VOL. XXXVIII. No. 2 FEBRUARY, 1960

THE STRUCTURAL ENGINEER

THE JOURNAL OF THE
INSTITUTION OF STRUCTURAL ENGINEERS

Brinsworth Steel Strip Mill

PART I by Donovan H. Lee (Member of Council) and G. O. Kee

PART II by N. Lancaster

Folded Plate Construction : An Investigation of Collapse Conditions

by A. R. Dykes (Associate-Member)

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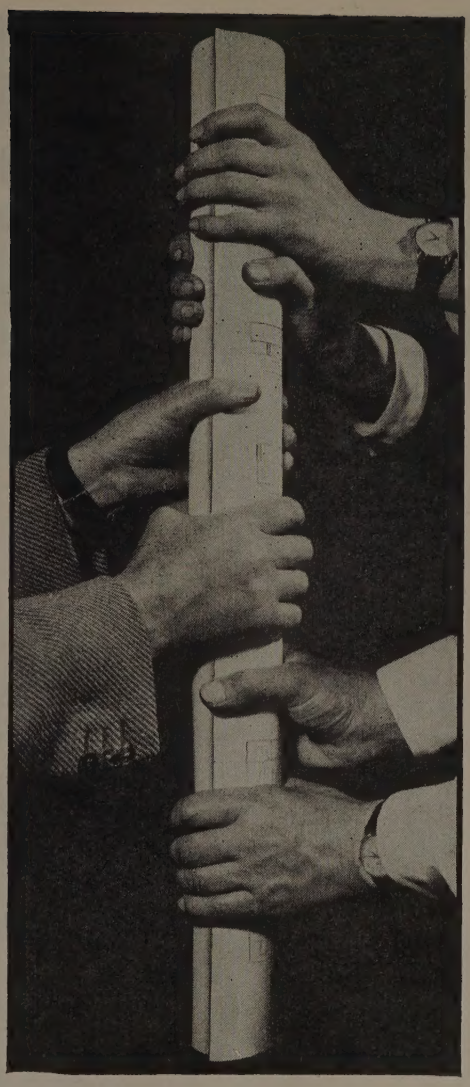

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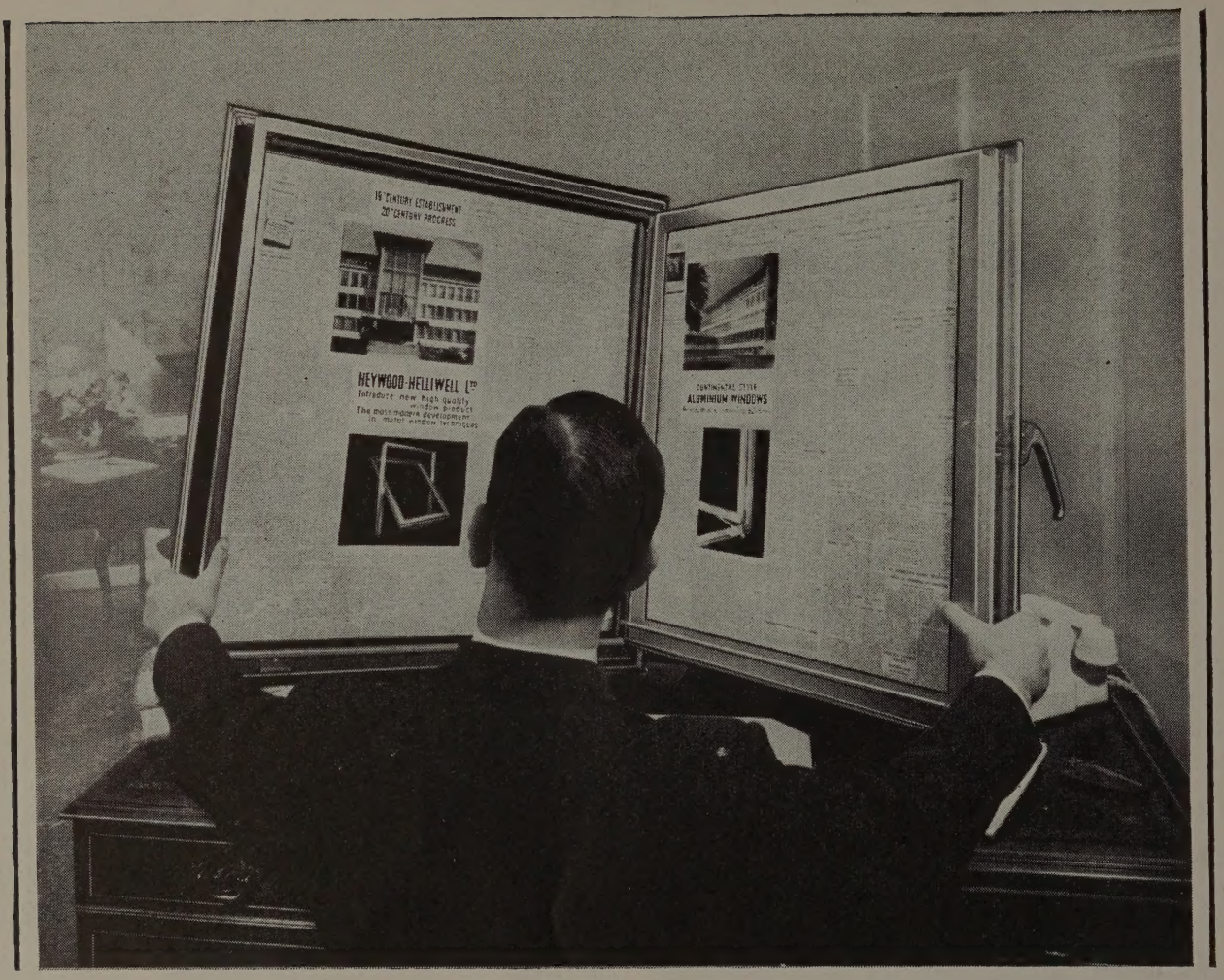

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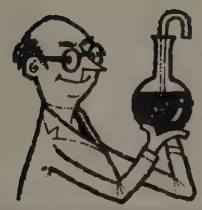

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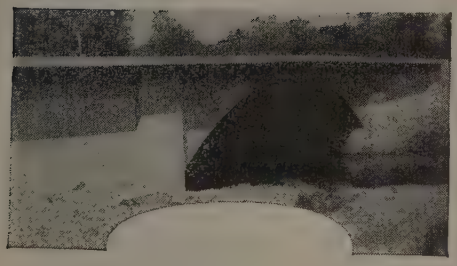

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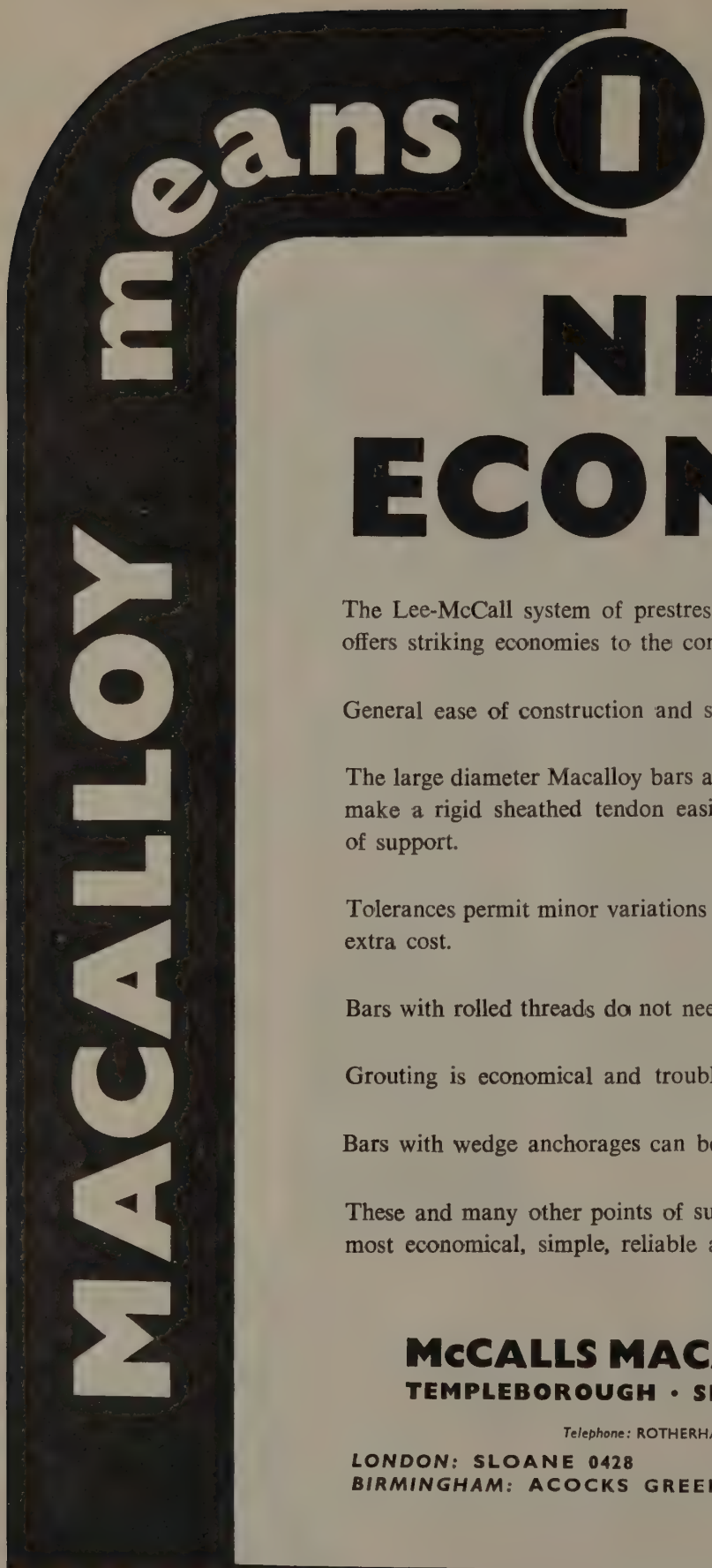

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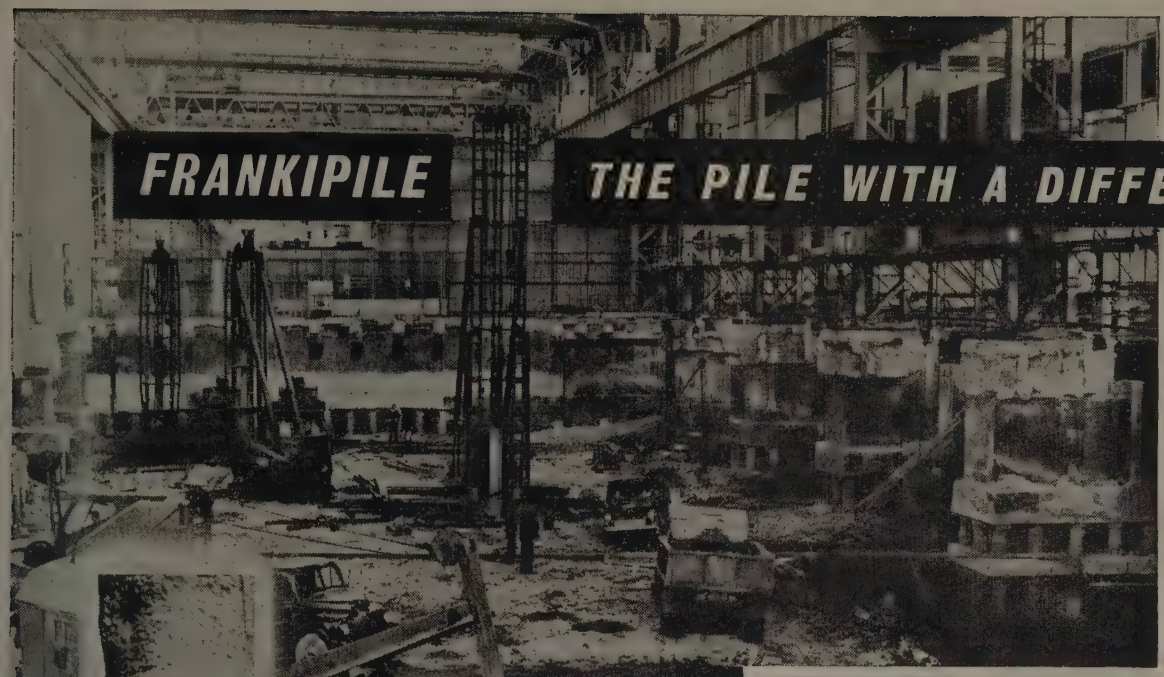

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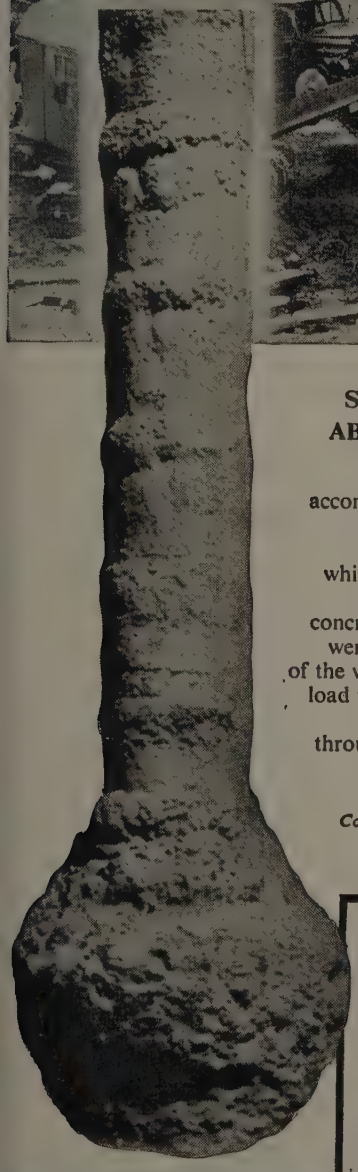

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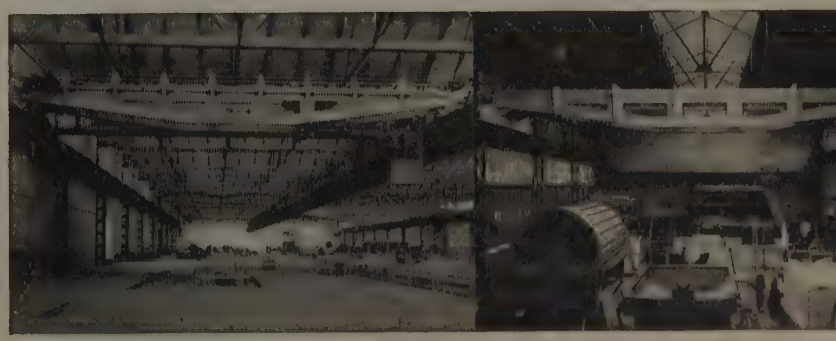

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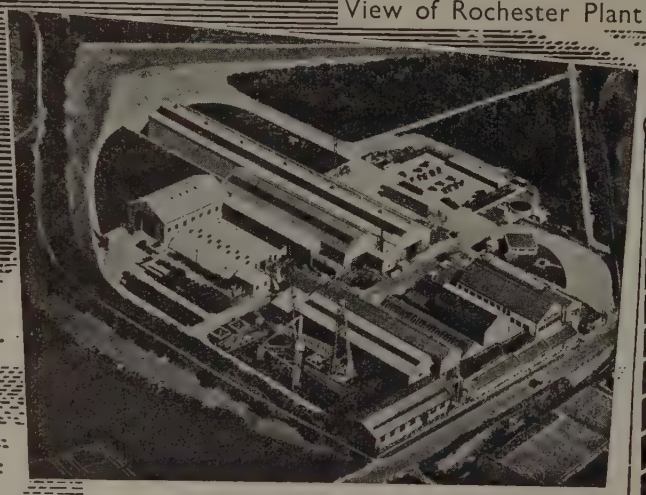

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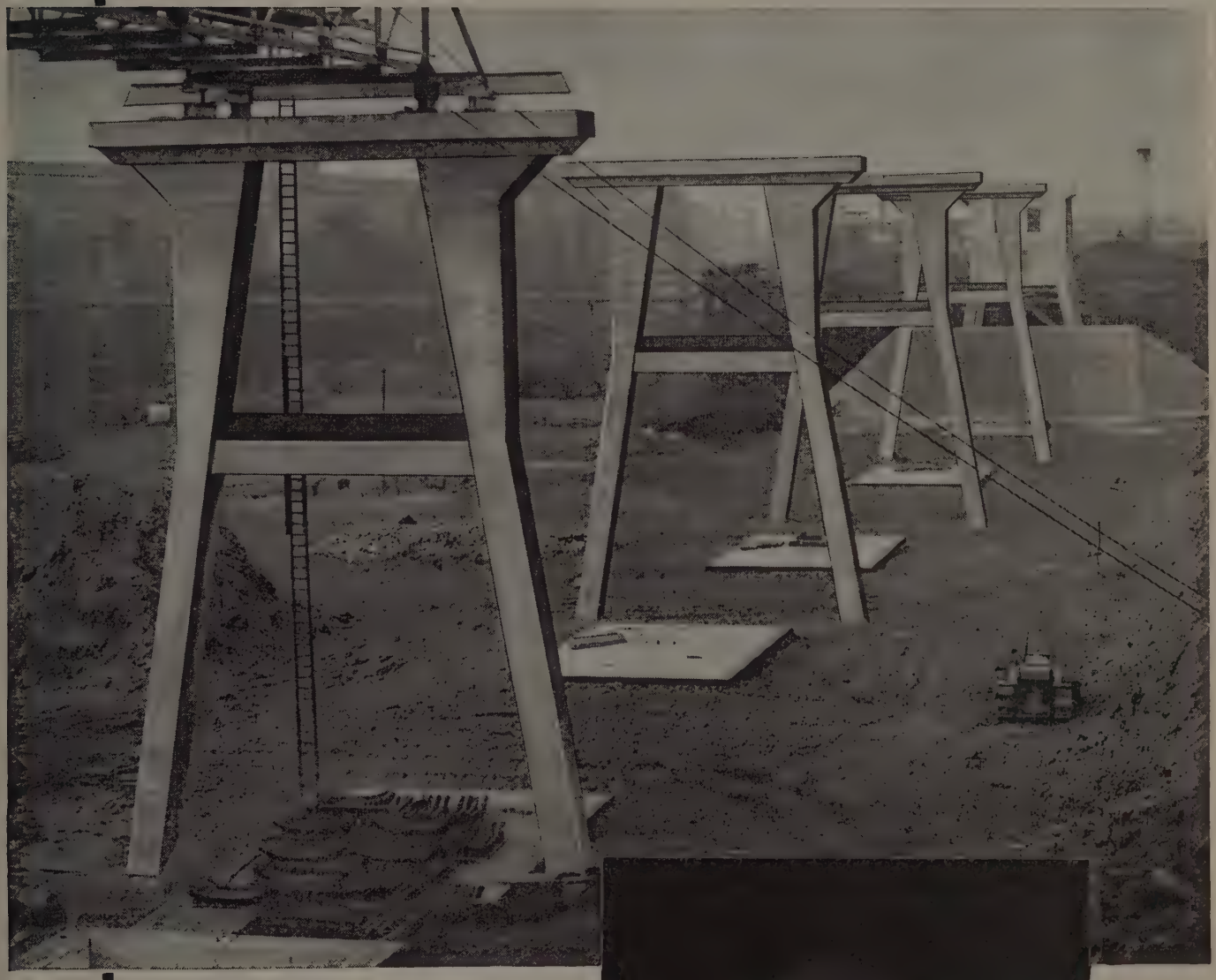

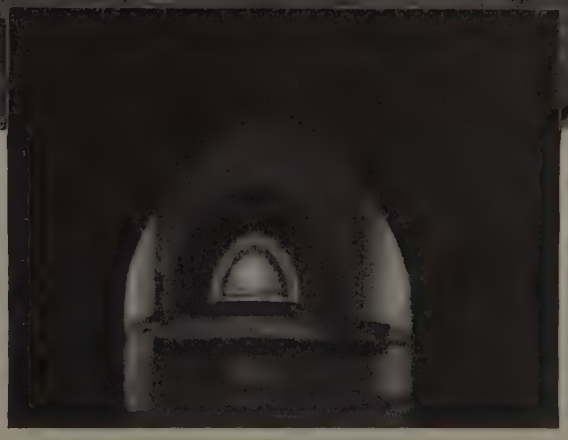

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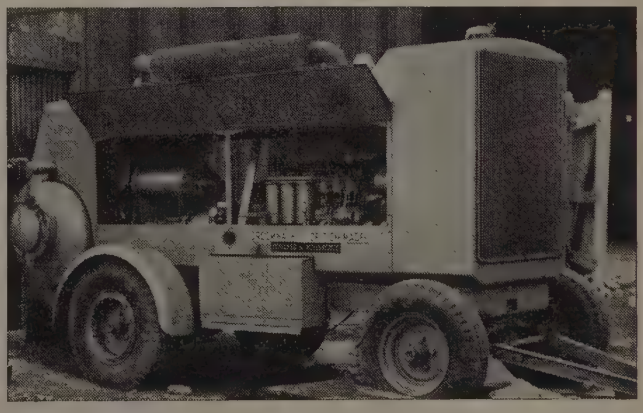

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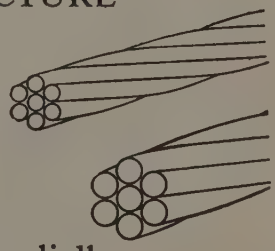

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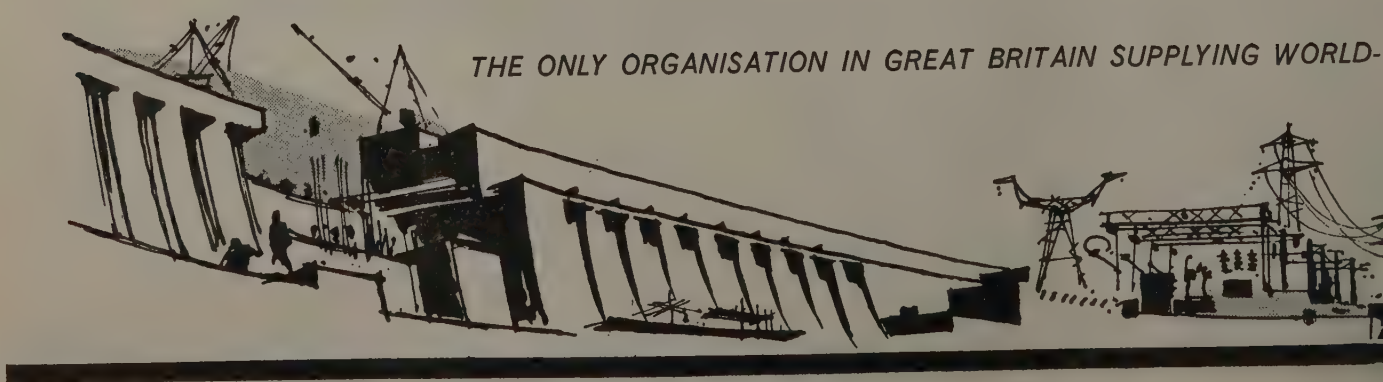

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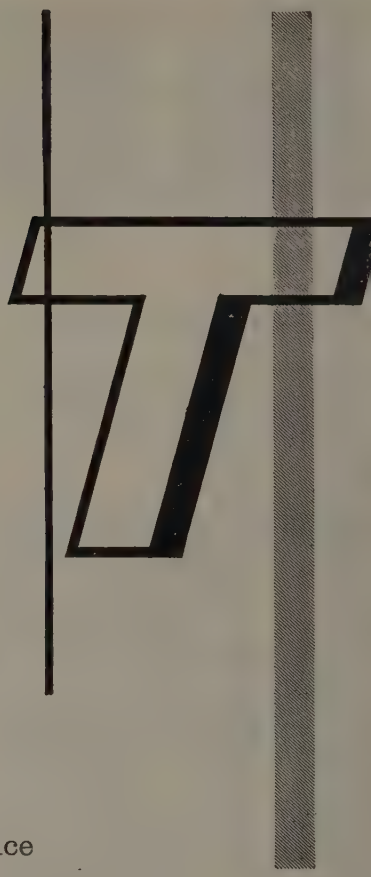

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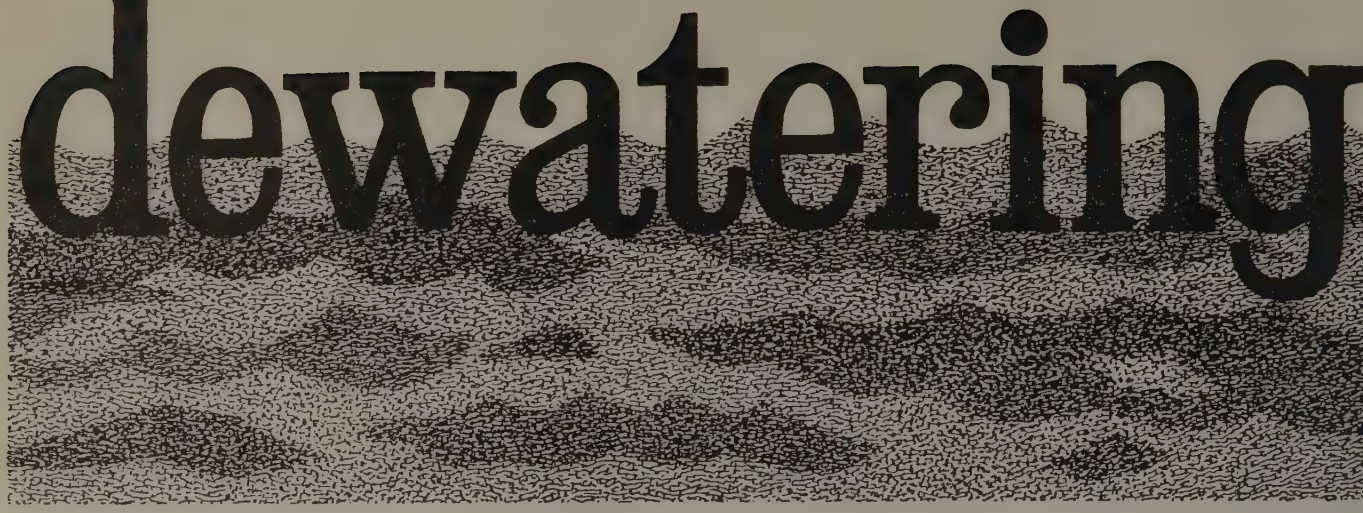

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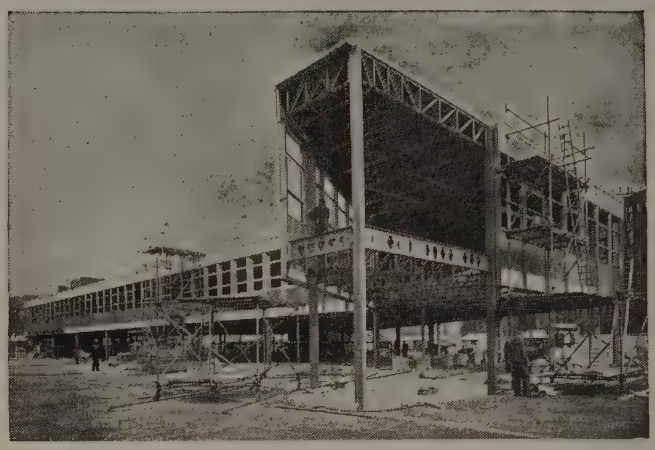

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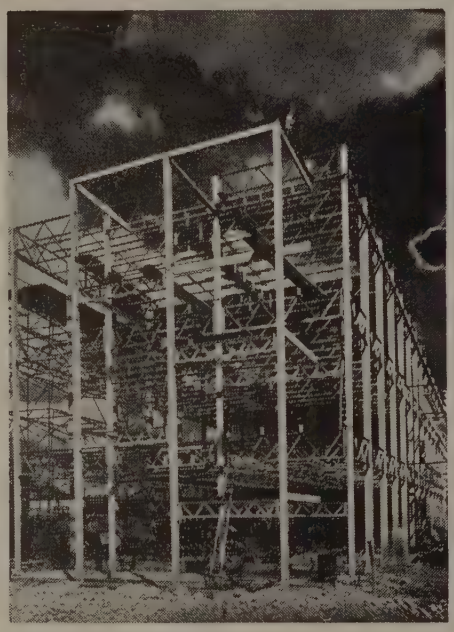

YORK. For the City of York a Grammar School. Sommerfelds designed the Steelwork on a 3' 4" modular grid allowing complete freedom for the Architect to use curtain walling and internal arrangements.
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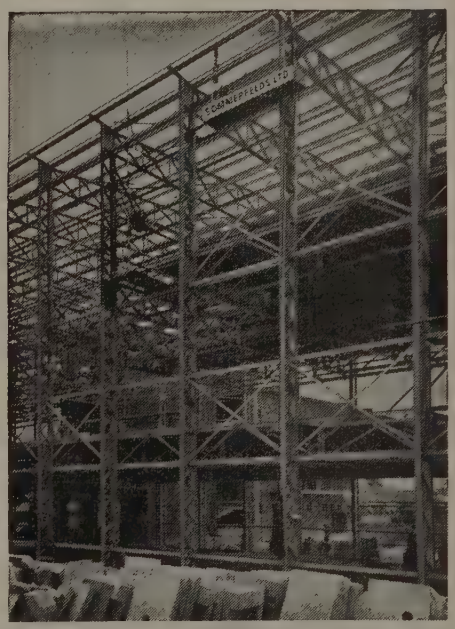

I.C.I. For I C.I. a Laboratory Block. A multi-storey building with a height to eaves of 44-feet and uninterrupted spans of 50-feet on each floor. Deep Lattice Beams and light stanchions were used with considerable saving in steel requirements.
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Brinsworth Steel Strip Mill *

PART I.

by Donovan H. Lee, B.Sc. (Eng.), M.I.Struct.E., M.I.C.E., M.I.Mech.E. (Member of Council)

and

G. O. Kee, B.Sc.(Eng.), A.M.I.C.E.

Introduction

The demand for steel strip has increased much more in recent years than that for other forms of steel, and as part of the national plan for development, the Steel, Peech and Tozer branch of United Steel Companies Ltd., put in hand in late 1954 a scheme to provide a new strip mill at Brinsworth.

Their present works on the north side of the main road between Sheffield and Rotherham produces around 1,100,000 ingot tons of steel annually of rolled and forged products such as billets, blooms, bars, strip, wheels, tyres, axles and springs.

The new mill was planned on the south side of the road at an estimated cost of £3.5 m. to produce hot rolled strip up to 18 in. wide in various qualities, including mild steel and stainless.

A pickling plant was included in the project and provision was made for cold rolling the product of the hot mill at a future date.

The scheme now described covers the production of coiled strip from slabs provided from the existing works and the production of H.R.P. and O. strip, slit if necessary to narrow widths and/or in exact lengths.

The constructional work commenced in July, 1955, and the first trial run of the mill took place on June 10, 1957. It is thought, even disregarding the large quantity of bulk excavation, that this was an achievement not previously equalled. Miscellaneous extra work and the pickling plant took until January, 1958, to complete. By that date, the mill was in regular production.

Site Layout

Open land provided adequate space and permitted railway access with small gradients from the existing works, subject, however, to considerable bulk excavation and the removal of most of one side of a hill to form a level area of sufficient extent. The site was originally as shown by Fig. 2, the lowest part being 70 ft. below the top of the hill seen in the background.

Geological

The subsoil strata consist largely of carboniferous sandstone, shale and siltstone; some of the latter, while of adequate bearing capacity in the natural state, deteriorates on exposure. At the low (north-west) part of the site alluvial deposit of poor bearing value overlays the carboniferous strata. To avoid risk of settlement the foundations were mostly taken down to rock.

Contracts for Excavation and Constructional Work

The constructional work was divided into a series of contracts placed as information became available and the design work was completed.

The first contract was for an access road along the north of the site. The second was for the bulk excavation including the railway cutting and the formation for the railway tracks. The bulk excavation work had to be done in two stages to allow the foundations of the mill to be started promptly, and also to permit the diversion of the main works water supply, which crossed the site, to its new position during a convenient shut-down period. This diversion was the subject of a separate contract.

Bulk Excavation and Site Levelling

To obtain suitable gradients for the access by road and rail, very large quantities of excavation were necessary; a small quantity of the resulting material was used to raise levels over the west of the site and the remainder removed. Fig. 3 shows the progress made about three months after placing the contract.

Much of the excavation was in rock. For many of the foundations, even very small settlements could not be tolerated and to reach rock the foundations in the north-west of the site had to be taken 15 ft. below the original surface and still more below the final surface. Under the slab bay, because of the very high loading to be expected, often 12 ft. of steel slabs, trenches 16 in. wide were excavated through the alluvial deposit at 7 ft. centres, also down to the rock, and filled with mass concrete; similar trenches were also provided under the furnaces and other heavy plant.

The section shown by Fig. 4 shows this and is taken east to west through the furnaces, scale pit, pumphouse and filter house, and shows the fill at the west end of the site.

For the lighter loadings of small structures on the north west part of the site bored piles were used. Over nearly half the site of the main building no excavation was necessary to reduce levels, but over 450,000 cu. yds. of bulk excavation was required over

* *Paper to be read before the Institution of Structural Engineers, at 11, Upper Belgrave Street, London, S.W.1., on Thursday, 11th February, 1960, at 6 p.m*

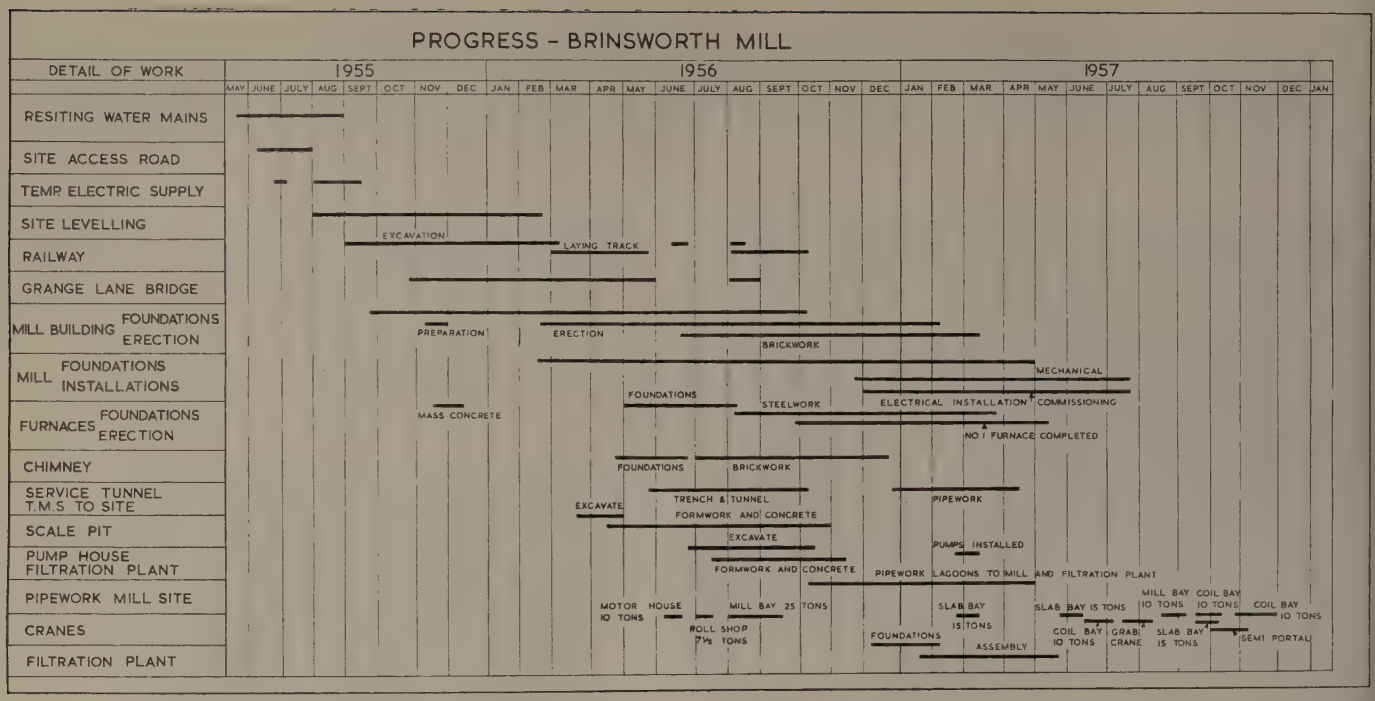

Fig. 1.—Progress—Brinsworth Mill.

the southern part of the site and in the railway approach, which had to be in a cutting for almost the whole length. Of this quantity about 325,000 cu. yds. was in rock.

Blasting was needed to loosen much of the rock which could then mostly be removed by excavators without further breaking up. The charges were inserted in holes drilled from above and near to the working face with micro-second delays between fusing adjacent holes to avoid risk of damage by earth shock to structures some distance away. The charges varied, depending on the hardness of the rock, from 30 lb. upwards of open cast gelignite per hole. Not more than 150 lb. was detonated at a time and tests were carried out at the nearest buildings to ensure that the vibrations were not of a dangerous order.

Deep and shallow land drains were run generally across the site from east to west and collected by an open main drain to the west of the site. The early installation of the land drains helped materially to keep the site clear of water during the bulk excavation and the later construction.

Concrete and Reinforced Concrete Work

The substructure of the slab re-heating furnaces, flues, recuperators, chimneys, roughing mill stands, run-out table and the complicated basement construction shown by Fig. 5, together with the forced air duct, scale water flume, transformer pits and the building foundations, was carried out in one contract.

This section has been taken running north to south approximately on the line of rougher No. 4 and through the acid neutralisation point.

The finishing stands, coilers and coil conveyors taking the coils to the coil processing bay were placed with another contractor when it was found difficult for one contractor to keep up to the programme for the substructure work.

The mill stands foundations were generally heavy blocks of concrete lightly reinforced, penetrated by a number of ducts, trenches and tunnels for services, cooling water flumes and access to the holding down bolt bearing plates.

For the reinforced concrete work the mix generally was 1 : 2 : 4, and weigh batching plants were used. On contracts covering the mill substructure, scale pit and pump house, concrete pumps were also used. The large aggregate varied from 1 in. maximum size for mass concrete and 1 in. and ¾ in. for the reinforced concrete work. The sand conformed to Class A of B.S. 882 then in force. Together with the various structures outside the mill building the total concrete quantity exceeded 30,000 cu. yds.

The external face of basement walls was coated with a bitumen solution to keep out damp. No water pressure was expected because of the land drains provided, but all structures below ground were designed for possible flooding of the sub-soil. The deeper pits for the transformers were tanked by asphalt

For the bedding of the bases of heavy plant, such as the roll stands, expanding cement grout was used to avoid uneven support by shrinkage ; for concreting holding down bolts in their ducts or pockets, however, fine concrete or ordinary cement grout was used.

The foundations for the roll grinders were separated from the remainder of the structure by casting them on studded rubber matting with an air gap at the sides to isolate the machines from the mill vibrations so that the rolls could be accurately ground.

The scale pit and pump house constructed to the west of the mill comprised a concrete pit 88 ft. x

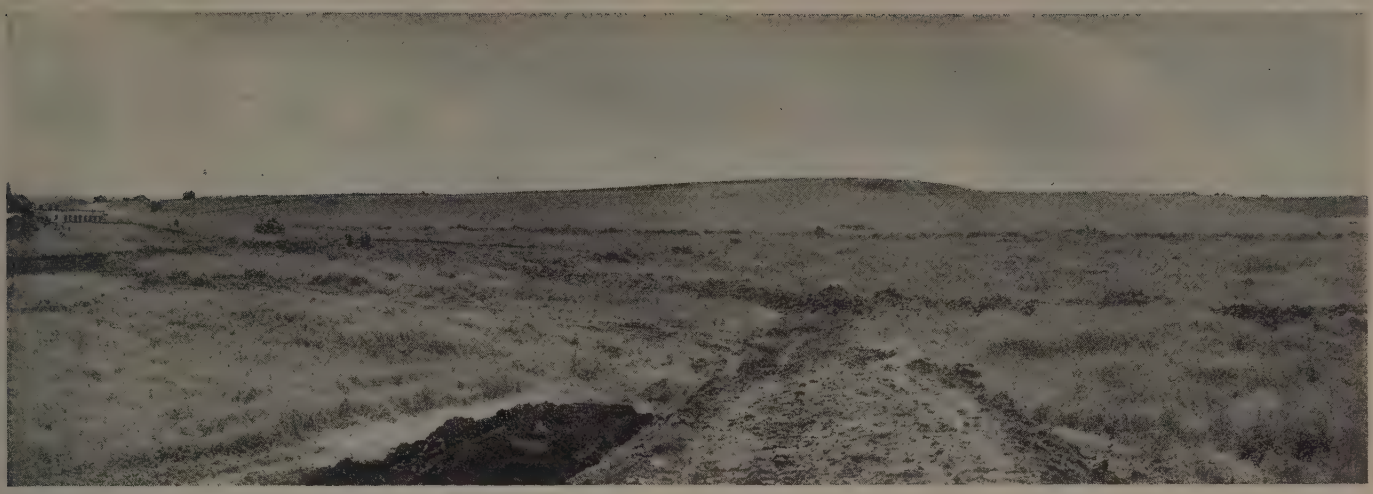

Fig. 2.

20 ft. wide by 34 ft. deep, and the pump house 80 ft. x 36 ft. The bottom of the pit was 45 ft. and the pump house floor 36 ft. below the general mill floor level. As the filter house was built on some 12 ft. to 15 ft. of selected hard fill, the filter tanks were founded on columns constructed before the fill was placed; the fill under the house was later consolidated with injected grout to reduce possible future settlement.

The 160 ft. high brick chimney of the slab re-heating furnaces was sited adjacent to the deep excavation for the scale pit, and 508 cu. yds. of mass concrete was required for the base of this chimney to extend it down to rock.

Service Trenches

A concrete service trench, varying in section, but generally about 6 ft. wide by 8 ft. deep, was provided for the pipe work and cables running the full length of the mill. Similar trenches extended to the pump house, filter house and cooling water tower, to the west of the mill, and also across the mill to the pickling plant, these being covered with precast concrete units set in sand and bitumen.

A service trench was also run from the main works to the north west corner of the mill under the Sheffield Road and another road. It was not permitted to disturb the Sheffield Road, so a tunnel under it was driven formed of 8 ft. diameter pre-cast concrete sections bolted together. The construction through the marl did not present any difficulties, although some water was present, and the space outside the lining was grouted to prevent settlement of the road and leakage of sub-soil water into the tunnel. The other road was also crossed by tunnel, but this was of box form constructed by cut-and-cover.

Floor Finishes

The floor in the motor room was finished with oil-resistant tiles. The concrete floor adjacent to the mill machinery was finished with a non-slip screeded surface treated with a surface hardener.

In the slab storage bay, where the loading from the slabs over the area of the stack may be up to $1\frac{1}{2}$ tons per sq. ft., 9 in. of ungraded slag was covered with a further 6 in. of crushed slag, blinded with dust, except for the area where the slabs are prepared, which was covered with large pre-cast concrete slabs $4\frac{1}{2}$ in. thick to allow for subsequent relevelling as might prove necessary.

In the coil bay the part of the floor area which had been excavated was finished with Prodorite tiles laid on a concrete slab. The part which had to be filled to level was finished with Stelcon slabs laid on sand and slag so that a level surface could be restored in the event of undue settlement under the very high loading.

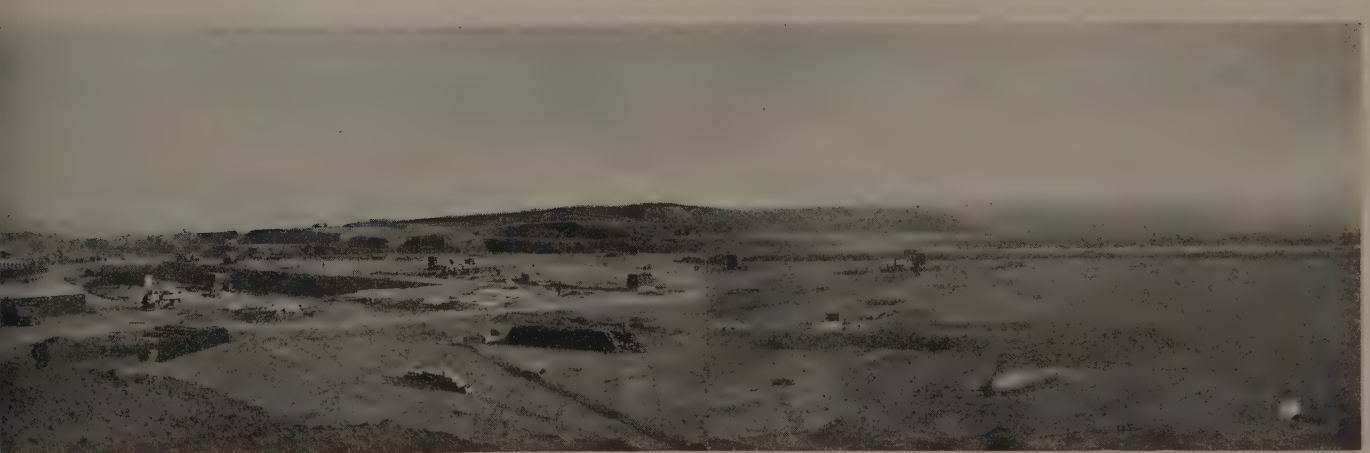

Fig. 3.

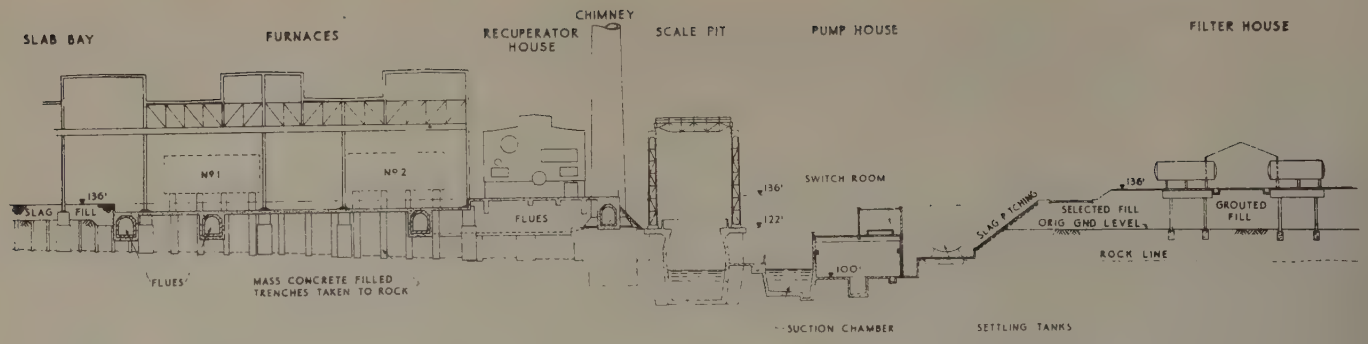

Fig. 4.—East-West Section.

Pickling Plant

The pickling plant was constructed to the south of the mill building, together with the acid recovery treatment plant. This work was complicated by the need to transfer one line of pickling tanks from the present works with the minimum of interruption and then complete the new second line while the first was in operation. This area is in excavated ground and did not involve very deep foundations, but there were some 300 ft. of service trenches, similar to those in the mill, connecting the pickling plant to the acid treatment plant.

In case of accidental spillage or leakage of acid, sulphate resistant cement was used for all the concrete of the substructure.

Roads

The roads were generally 20 ft. wide between precast curbs, with a base of 6 in. of rolled crusher run slag over 6 in. of rolled bank slag. The finish was ½ in. of bitumen-coated slag chippings on 3 in. of coarse bituminised slag. The formation was excavated to fall to one side where a land drain was provided outside the line of the curb.

Where levels were raised, the filling was selected surplus granular material or broken rock to minimise future consolidation, and settlement was thereby kept to low values. Nevertheless, it was unavoidable that some of the roads at the west of the site, where the filling was deep, would settle and need resurfacing ; however, this did not prove extensive.

Railways

The railway track was provided to main line standards owing to the severe loading conditions and consisted of 109 lb. per yd flat bottom rail with cast iron baseplates, elastic spikes and tanalised sleepers.

The rails were thermit welded at alternate joints, except at turnouts, so that rail joints are generally 120 ft. apart. This was done principally to obtain more experience on reduced maintenance without necessitating the extra cost of the usual precautions needed with long welded rails.

Grange Lane Bridge

In order not to interrupt the use of a private roadway and public footpath crossing the route of the approach railway and yet to enable the latter to be constructed, the bridge was built before the bulk excavation was done below for the railway cutting. This involved constructing the foundations at the bottom of holes about 24 ft. deep, constructing the piers and the bridge practically level with the surrounding ground and then excavating for the railway tracks between the piers. The existing water mains were diverted to come under the bridge at the correct levels and alignment before the construction of the bridge was commenced and were then carefully transferred to slings from the bridge before the soil was excavated below.

Fig. 6 shows the re-located water mains and h.t. electric cables just below the then existing surface of the ground, and temporarily supported to enable the bridge piers to be sunk below them ; Fig. 7 shows the bridge finished.

The bridge was designed in normal reinforced concrete because of heavy commitments elsewhere at that time for the supply of high tensile prestressing steel. It is designed for M.O.T. highway loading and constructed throughout of vibrated concrete of 1 : 2 : 4 mix and low water/cement ratio to give resistance to the acid atmosphere in this area. Because Messrs. Steel, Peech and Tozer are now largely using diesel locomotives, no smoke baffles were provided, but this proved a false economy as a steam crane promptly

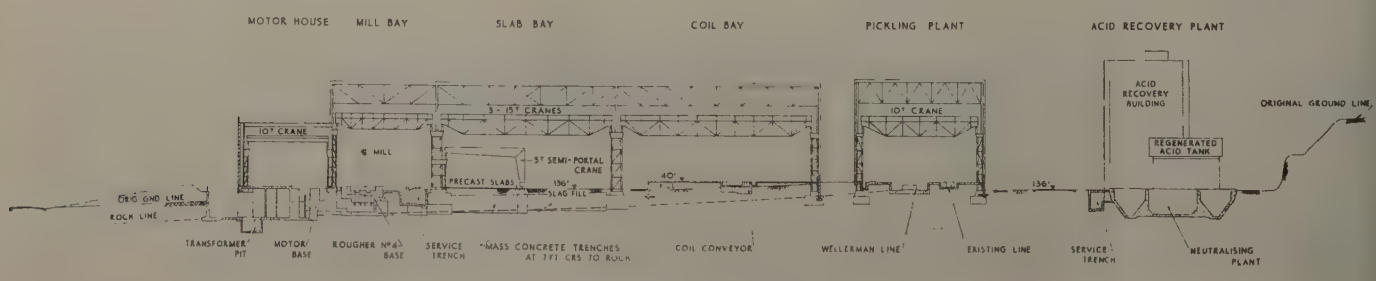

Fig. 5.—North-South Section.

Fig. 6.—Bridge under Construction, December, 1955.

caused smoke marking of the newly concreted beams.

The handrailing, made of steel tubing and welded steel panels, was shot blasted and aluminium sprayed to reduce subsequent maintenance painting. It was not painted and after the first year was not much discoloured. In a future similar case, however, the Authors would favourably consider a clear varnish finish. It was designed to be removed in sections in case of damage.

Amenity and Office Building

This building, in the foreground of Fig. 8, was planned to provide offices for the mill management on the first floor and amenities for the mill operatives on the lower level; it was sited so that the entrance is at the level of the service road and the first floor level with the floor of the mill. The welfare facilities provide for a total of 640 men and for an increase in the future to 896.

The building was carried on 65 No. 17 in. diameter bored concrete piles, taken to rock approximately 18 ft. down. Short extensions were constructed above ground up to floor level and filling was placed round them; the ground floor slab and beams were cast on this but designed as suspended to provide against settlement. The tower contains the water storage and air conditioning plant.

The first floor and roof are of solid reinforced concrete slabs and beams carried from the substructure by reinforced concrete columns.

The concrete for the bored piles was of 1 : 1½ : 3 mix and all other reinforced concrete work was of 1 : 2 : 4 mix. A plasticiser was incorporated in the concrete for the superstructure to assist placing of the high strength low slump concrete, which was compacted by internal vibration.

Close fitting formwork was used for the 1st floor and roof slabs and the exposed sides and soffits of beams; these surfaces were rubbed down on striking the formwork and plastering of ceilings was omitted.

The ground floor slab was sealed by a bituminous membrane to prevent lifting of the finish by vapour drawn through the slab.

To obtain improved resistance to the acid atmospheric conditions the mortar was generally 3 : 1 : 12 cement : lime : sand, with the addition of a plasticiser. Below ground level, 1 : 3 cement : sand mortar was used.

Window frames are of steel protected by hot dip galvanising, phosphating and an iron-oxide primer, with usual finish of decorative painting. Other external steel work, such as access ladders, was shot blasted and sprayed aluminium.

The panels between the artificial stone surrounds and mullions were faced with black vitreous tiling with white lead pointing.

As protection against damp and to retard the discoloration of the building by smoke and dust, all external brickwork and artificial stone surfaces were sprayed with silicone.

Services were generally located in ducts in the ground floor slab, or concealed by a demountable false ceiling over the ground floor main corridor.

The work was carried out during a period of shortage of skilled labour in the area and not all the necessary information was available at the start of the work, but working overtime, which was justified by the extra cost being less than the interest on the investment, resulted in the subsequent rapid progress shown by Fig. 1.

Mill Installation

The two furnaces are of the Rust Two-Zone fired continuous type, designed to heat slabs 28 ft. 6 in. long by 3 in. thick and up to 19 in. wide. Designed output for each furnace is 60 tons per hour and they are capable of a maximum output of 75 tons per hour. Each furnace is 60 ft. long and 30 ft. 6 in. wide, and fired with special low sulphur fuel oil. The burners are of the Rust Back Atomising type, nine of high capacity being provided in the tonnage zone and eleven of low capacity in the soaking zone.

The combustion air is wholly preheated in Schack Flue Tube Recuperators, the waste gas passing through tubes while the air passes over the outsides in counter-flow direction. Dampers are provided to permit the recuperators to be isolated for maintenance work.

Both furnaces are connected to the chimney referred to earlier which is 9 ft. 1 in. to 7 ft. 6 in. diameter; it is provided with a mid-feather wall at the base to prevent baffling when both furnaces are in use. Each furnace has a cold air fan and a waste gas fan of 22,000 c.f.m. and 70,000 c.f.m. capacity respectively at 15 in. w.g. and 2·5 in. w.g. Each zone of the furnace has a temperature controller

Fig. 7.

which automatically adjusts the oil, steam and air and comprehensive instrumentation is provided to ensure even distribution of the temperature.

Slabs are placed by overhead crane on the depiler grid surmounting a weighing platform. A hydraulically operated stack buffer is used to true up the piles of slabs and a depiler pusher, exerting a force of 7½ tons, with a stroke of 8 ft. 2 in., pushes the slabs on to the depiling platform. The depiler platform is 29 ft. 4 in. long by 23½ in. wide and is raised and lowered by rack and pinion gear, driven through worm reduction by a 50 h.p. motor.

The depiler platform is lowered until only the top slab is level with the furnace charging tables, the top slab is then pushed on to the furnace charging table. Each furnace is provided with a twin pusher exerting a force of 90 tons with a working stroke of 6 ft. 6 in.

The furnace discharge table is 132 ft. long and discharge bumpers are provided opposite each furnace. The shock of arresting the discharged slab is absorbed by friction type springs within a cylinder.

Any slabs distorted when discharged from the furnaces are rejected by gear placed between the two furnaces.

The mechanism for turning the slabs on edge before entering the horizontal edging stand is driven by a 50 h.p. motor through worm reduction gear.

The function of the horizontal edging stand, situated 42 ft. from the centre line of No. 2 furnace, is both edging and scale breaking. The water-lubricated roll bearings to this stand are of a synthetic resin, the rolls being driven through a Wellman Bibby coupling by a fly-wheel assisted 350 h.p. slip-ring induction motor and spur reduction gear to give a roll speed of 35-39 r.p.m.

A second manipulator follows the horizontal edger to turn down the slabs. From the horizontal edger to No. 1 roughing stand is 39 ft. which is sufficient to allow free run between the two stands.

Four roughing stands (Fig. 11) are placed so that there is free run between the first, second and third; the third and fourth are close coupled. The stands are two high with Pearlitic alloy spheroidal graphite rolls 24 in. long and 21 in. dia.; the roll bearings are synthetic resin, water lubricated and have automatic oil injection to prevent corrosion when standing idle.

Motors driving the four stands are respectively one 700 h.p. slip ring induction flywheel assisted, two 1,200 h.p. 428 r.p.m. synchronous and one 1,200 h.p. variable speed D.C. motor to permit speed matching of No. 4 rougher to No. 3. Wellman Bibby couplings connect the roughing mill motors to their reduction gears.

A two-roll, overhung type, vertical edger is placed immediately in front of No. 3 rougher, the rolls being of indefinite chill quality Adamite alloy. The edger main drive is provided by a 150 h.p. motor through spur reduction gear and each housing traverse drive is by a 5 h.p. motor. The complete edger assembly can be traversed on the baseplate by a 7½ h.p. motor.

The roughing mill roller tables are water cooled from spray headers situated below roller level, the sprays being normally automatically controlled through a magnetic valve initiated electrically when the load comes on No. 4 rougher, shown in Fig. 13 with the furnaces behind.

A flying shear is located 151 ft. beyond No. 4 roughing stand for cropping the leading end of the strip before it enters the finishing stand, and also for tailing the end of the strip. The shear, which is of the rotary drum type, is capable of cutting off strip up to 18 in. wide and 1 in. thick at strip speeds up to 450 ft. per minute. Cropped ends fall into a steel chute and are collected in boxes below the roller table.

The roller table between the flying shear and the vertical edger is fitted with an adjustable switch and piler for the disposal of any cobbled strip; this can be cut up into suitable lengths by the flying shear. A cobble coiler, provided near No. 6 finishing stand, consists of a vertical coiler, tensioning rolls and a shear.

Two 20-in. vertical edgers are installed, one in front of No. 1 finishing stand, and one between Nos. 2 and 3 finishing stands; both are of the vertical two-roll overhung type, and the main roll drive is by 75 h.p. motors.

The first of the six finishing stands is 48 ft. beyond the flying shear. These are four-high stands, having work rolls 14 in. dia. and 23 in. long of indefinite chill Nironite alloy in the case of Nos. 1, 2 and 3, and of indefinite chill Manganite alloy for Nos. 4, 5 and 6. The complete work and back-up roll assembly can be traversed sideways by a hydraulic cylinder. The work roll bearings are Timken four-row tapered roller type, and the back-up roll bearings are of Skefko four-row parallel roller type. No. 1 stand is driven by a 1,200 h.p. variable speed D.C. motor having a speed range of 425/650 r.p.m. which is coupled to a

Fig. 8.—This building contains an amenity centre on the ground floor and mill management offices on the first floor.

Fig. 9.—Progress of erection of steelwork of mill and mill motor bays by 7th August, 1956.

spur reduction gear of 6·47 to 1 to give a roll speed of 77·5 to 155 r.p.m. Motors for Nos. 2, 3, 4 and 5 stands are 1,750 h.p. variable speed D.C., coupled to spur reduction gears, except for No. 5 which is driven directly. No. 6 stand is also driven directly but by a 1,200 h.p. variable speed D.C. motor. The motors of the first four stands are connected to their reduction gears by Wellman Bibby couplings.

Loop lifters are provided between each of the finishing stands, and can be operated manually, automatically or semi-automatically. Under automatic operation, initiation is by load relays, with a speed connection circuit which corrects the main drive motor speeds to bring the loop to a pre-set value.

High pressure de-scaling equipment is located in front of Nos. 1, 2 and 3 roughing stands and in front of No. 1 finishing stand. A pressure of 1,500 lb/sq. in. is provided by a multi-stage centrifugal pump having a capacity of 400 gallons per minute. The water supply is filtered and drawn from an overhead tank to give a positive suction head.

The run-out table from No. 6. finishing stand to the pinch rolls, preceding the No. 1 coiler, has a length of 160 ft. with 105 rollers. 35 motors each drive three rollers through Vee belts and are controlled in three groups by variable frequency speedmasters. Cooling sprays are provided to ensure that the strip reaches the coilers at the desired temperature.

Thickness gauging is carried out by radioactive absorption technique. The radioactive source, provided from the atomic piles at Harwell, is located on the run-out table, and a detector unit is mounted above the strip in a water-cooled housing.The amount of radiation reaching the detector is dependent on the thickness of the strip. The deviation of the actual thickness from the desired thickness is indicated on a dial in the finishing mill pulpit, and any variations show as red, amber and green lights and a permanent record is provided by a teleprinter.

Fig. 10.—Motor room—general view.

Fig. 11.—View of mill from furnace end.

An optical width gauging device follows automatically the two edges of the strip ; deviation from standard is indicated on a 36 in. dia. dial above the run-out table.

Two 20 in. coilers are provided and are driven by 175 h.p. motors having speed control from zero to 1620 r.p.m. The nine cluster rollers are operated by air cylinders, thus providing a resilient medium to absorb the shock of the entering strip. The coilers are preceded by pinch rolls which maintain tension in the strip after the tail end has left No. 6 finishing stand.

Completed coils are pushed off the coiler drum by push-off gear on to a travelling carriage with a down-ender arm which tilts through 90°, turning the coil into the horizontal position. The coil is then lifted to permit the down-ender to be withdrawn and the lowering of the coil lift places the coil on a conveyor which then moves forward. These operations take place automatically, timed by a series of limit switches.

The total length of the coil conveyor is 634 ft. and is in three sections, each driven through a Vulcan Sinclair fluid coupling worm reduction and spur reduction gear. The first 40 ft. section has a conveyor speed of 60 ft. per minute. The coils are transferred from the first to the second sections of the conveyor, which are at right angles, by means of a whirligig consisting of a four-armed turntable, mounted on a vertical spindle having both vertical and rotational motion. The conveyor places the coil on one arm of the whirligig, which is lifted and rotated and lowers the coil on to the second section of the conveyor. At the end of the 183 ft. long second section is a similar whirligig. Two coil bundling stations are provided in the third section. At the extreme end of the conveyor system there is a gravity conveyor to receive any coils which may not have been removed from the power-driven conveyor.

The inspection line is designed to uncoil and re-coil strip at a speed of 150 ft. per minute, and has a capacity of 19 in. wide and 0·25 in. thick. It consists of a take-off reel, a pinch roll and leveller unit, roller tables, shear, tension reel, and coil handling equipment.

Two sets of equipment are installed for cutting to length and can deal with a width of 18 in. and length from 2 ft. to 30 ft. Each set consists of coil handling equipment, uncoiler, 3-roll flattener, an edge trimming unit, scrap cutter, scrap shute, strip leveller, flying shear, belt conveyor, pinch roll unit, piler, side pusher, roller tables and weighbridge.

The estimated total water consumption of the mill in full production is 608,000 gallons per hour, of which the run-out table and coiler cooling take 240,000 and the furnace cooling 102,000. Because there was little spare capacity in the existing main works river water supply a re-circulation system was used and only the necessary make-up water, approximately 30,000 gallons per hour, is taken from the existing supply. The scale water is kept separate from the furnace water to avoid contamination ; the latter is drawn from the base of the cooling tower by a pump of 2,000 g.p.m. capacity. A similar pump is provided for returning the water to the top of the cooling tower, and automatic arrangement is provided for supplying water from the main works supply in emergency. The scale water flows by gravity below the floor of the mill in a flume lined partly with cast iron and partly with silica tiles, and passes at a depth of about 15 ft. into the scale water settling pit from which the scale is grabbed and returned to the melting shop (Fig. 14).

Approximately 35,000 lb. per hour of waste heat steam is used at a pressure of approximately 180 lb/sq. in. and is provided from the main works. It is used for heating the fuel oil to an automatically controlled atomising temperature of 225°F., shop

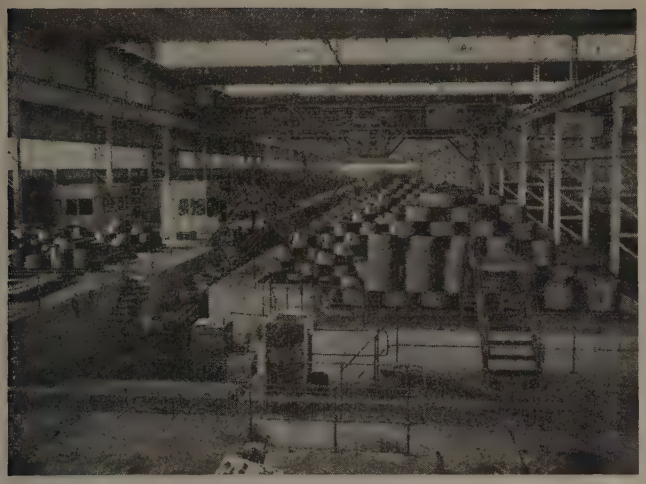

Fig. 12.—General view of the coil bay, showing part of the 600 ft. long coil conveyor on left.

heating and scale blowing at the finishing mill roll stands. It is also used in the amenity and office building through a calorifier and heat exchanger with circulating pumps for hot water supply and radiators and warming the ventilating air for which ducts are provided throughout the building. The air intake is in the tower where the air is first passed through an oil filter to remove suspended matter and is then warmed, with thermostatic control, and forced into the duct distribution system with sufficient pressure to provide a slight plenum and prevent draughts at doorways. The heating system is also provided with thermostatic controls reducing the need for frequent attention.

The fuel oil is supplied from the main works' ring main at a pressure of 180 lb/sq. in.

An air compressor of 750 cu. ft. per minute capacity was installed. Only a fraction of this quantity is required for the mill; the large compressor was installed to supplement the main works compressors which were becoming overloaded.

Oxygen, which is mainly used for de-seaming slabs, also coke oven gas, is obtained from the main works. Supply of water for the fire hydrant system is obtained from the Sheffield Corporation mains because of it being of adequate pressure to reach the higher parts of the roof without the use of pumps.

Electrical Installation

Electrical power supply is at 11,000 volts, to a thirteen-panel 250 m.v.a. compound filled metal-clad switch-board located near the centre of the motor room. The rectifier house adjacent accommodates 7,000 k.w. of grid controlled rectifiers, giving 360/600 variable voltage D.C. and 1,000 k.w. of constant voltage rectifiers for 230 volts general power for overhead cranes and auxiliaries. All the rectifiers are of the multi-anode mercury arc type. Bower transformers of capacity totalling 15,000 k.v.a. are located in open-fronted compartments at basement level below the motor house floor and adjacent to the switch and rectifier rooms. Lighting in the production bays is of the blended type, 400 w. mercury vapour and 1,000w. tungsten type. Fluorescent lighting is installed in the roll shop, motor room and repair shop.

The project was carried out under the direction of Mr. V. Watkins, Chief Engineer, with Mr. J. Waller and Mr. L. Parkin responsible respectively for the mechanical and electrical work. The Authors were responsible for the design and supervision of the civil and structural engineering work below rail level and some structural work in buildings and bridge above. The United Steel Structural Company were responsible for the mill building and the structural steel dealt with in Part 2.

The constructional contracts and contractors were as follows :—

North access road ; Arthur Cooper & Sons Ltd.
Bulk excavation ; Sir Alfred McAlpine & Son Ltd.
Main concrete work in mill; George Longden & Sons Ltd.
Diversion of existing water mains ; Jeavons & Co. Ltd.
Railway track ; Industrial Sidings Ltd.
Grange Lane Bridge and Weighbridge Pit ; Arthur Cooper & Sons Ltd.
Additional concrete work in mill ; Sir Alfred McAlpine & Son Ltd.
Scale pit & pump house ; Sir Alfred McAlpine & Son Ltd.
Tunnel under Sheffield Road, etc ; Henry Boot & Sons Ltd.
Fencing ; Darlington Fencing Co. Ltd.
Piling for amenity & office building ; Cementation Co. Ltd.
Concrete substructure of ditto ; Sir Alfred McAlpine & Son Ltd.
Superstructure of ditto ; Bovis Ltd.
Substructure of pickling plant and acid recovery plant ; Henry Boot & Sons Ltd.

In addition, various items of work were carried out by nominated sub-contractors, of which the following are examples :—

Murex Ltd. ; Thermit welding of rails.

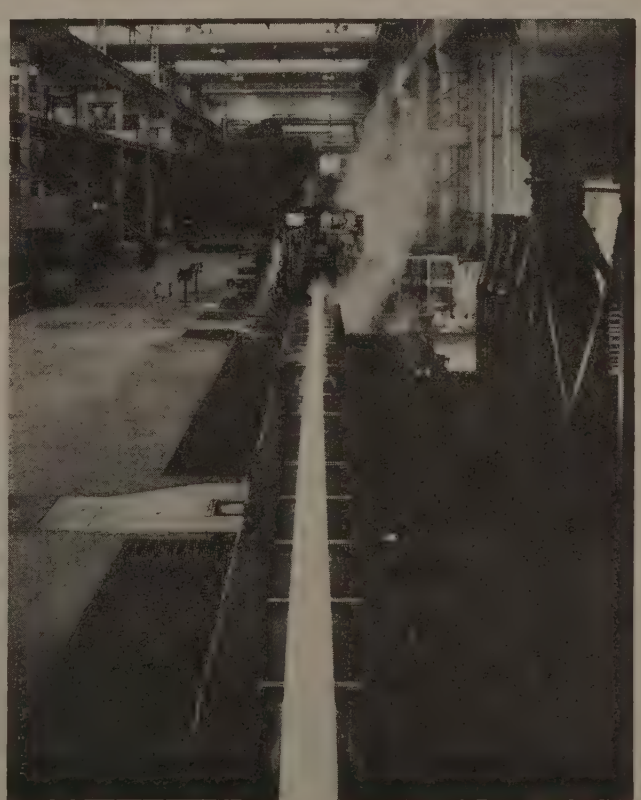

Fig. 13.—View taken from finishing stand, looking towards the roughing stands, and the slab furnaces in the background. (About September, 1957).

Cementation Co. Ltd.; Injection of grout for consolidation of fill in filter house area.
Brightside Engineering Co; Heating and ventilation of amenity and office building.
Workington Iron & Steel Co.; Railway rails and fastenings.

The cost of the whole project was approximately £4m. The total cost of the constructional work including the amenity and office Building, but excluding the mill building and other work above rail level, was approximately £1,100,000.

Other principal contracts were :—
Loewy Engineering Co. Ltd.; Mill machinery.
English Electric Co. Ltd.; Electrical installation.
Stein & Atkinson, Ltd.; Furnaces.

PART II.

by N. Lancaster

Superstructure Steelwork

When the opportunity occurs to produce a super structure design for steelwork plant buildings on a clear site, every endeavour must be made to take into careful consideration many features, all of which will in greater or lesser degree affect the efficiency of the structure in respect of its designed purpose. A building structure may be regarded as a design subject strictly on the basis of current requirements; however such buildings have relatively long lives, and in the course of such life it is almost certain that changes will be required in order to comply with the development of working techniques and changes in processing methods. For instance, it may become necessary to remove columns here and there and consequently provide larger span crane girders in order to simplify the organisation of a particular modification to production Alternatively, it is not unknown for a general upgrading of crane capacity to be requested over a part, if not the whole, of a bay or bays to accommodate modernised plant.

It is now the general practice to provide a more spacious layout of buildings than was formerly the case. This is a desirable feature from several points of view as production is assisted and plant and building maintenance considerably eased in consequence. In the case under consideration it was decided to employ comparatively wide bays with a roof form which provides at once for adequate natural ventilation and lighting. Further, the problems associated with roof drainage and particularly in respect of multi-bay buildings are facilitated and the employment of the form of construction to be described results in a final arrangement having a number of advantages over more conventional outlines.

Apart from providing clear spans and a generally open aspect to the buildings, maintenance work in respect of superstructures and plant, including cranes, is considerably eased by careful consideration of stairways and access platforms so that safe and easy access may be obtained to the various positions at which work is to be done. This is particularly necessary for work on cranes where good lighting and a safe working position is an absolute necessity. Such conditions apply in a comparative degree to all work which has of necessity to be done above floor level, and the provision of satisfactory means to this end is most important.

The mill buildings have been designed throughout in a " simple " form and continuity through a transverse or longitudinal section has been discounted. The various features noted above have been employed in the strip mill buildings considered in this paper.

" Fitness of purpose " has been taken as a basis for the primary development and the subsequent design and construction of various structures erected by the United Steel Companies for many years and the experience gained has culminated in the production of the layout of the steelwork for the strip mill.

The general layout of the several bays is shown in Figs. 10, 11, 12 and the diagram Fig. 15. Of the four longitudinal bays each approximately 800 ft. long, the motor house has a roof span of 46 ft. 6 in. and the mill bay 56 ft., the slab bay 96 ft. and the coil bay 106 ft.

The roof covering consists of Robertson Q-Deck and the side and gable cladding are in Robertson Protected Metal Sheet with the exception of the frontage of the motor house which is in brickwork. This wall is self-supporting in respect of dead weight and has steel framing to provide satisfactory lateral support against wind loading. The roof construction is generally of lattice girders carrying Castella roof beams, and natural lighting is provided by glazing the entire vertical surfaces of all the main roof spans. The roof outline is in High-Low construction consisting of alternate high and low bays providing a high value of illumination throughout the entire length of the building (Fig. 16). Natural ventilation is provided by the use of 48 in. throat Robertson ridge ventilators applied to the roof surfaces as required, especially over the mill area.

In general the columns are of latticed construction involving the use of wide flange beams with roof legs of Castella construction similar to that employed for the roof beams. The crane girders are in all welded construction throughout having a single web, and are designed to be self sufficient for all the horizontal and vertical forces which may be applied to them during work. The cranes in each of the bays are as indicated in the Table.

	Roll Shop	*Motor House*	*Mill Bay*		*Slab Bay*	*Coil Bay*
Span feet	42	42	50		90	100
Capacity tons	1 @ 7	1 @ 10	1 @ 25	1 @ 10	3 @ 15	3 @ 10
Hoist Speed ft. per min	25	24	36	45	50	45
Long Travel ft. per min.	150	170	200	320	350	450
Cross Travel speed ft. per min.	75	80	100	150	150	150

Fig. 14.—Water used in the mill cooling and scale flushing systems returns to this large scale pit, where the scale is allowed to settle out.

Walkways for access along the lines of columns are provided by spacing the crane legs apart sufficiently to allow a 6 ft. wide walkway at 20 ft. above floor level for the full length of the buildings. Crane access is obtained from these walkways and provision is made for cleaning the interior surfaces of the glazing in the roof. Access to the electric lighting fittings is obtained from the same galleries.

It is thought that some of the features of detail design may be of interest and information is given in respect of these items in the following paragraphs, and whilst the principles suggested are those in general usage for work of this type, specific details apply to the strip mill buildings with which we are concerned.

Roof Construction

Lattice roof girders are positioned at 34 ft. 9 ins. centres throughout the mill, slab and coil bays, each alternative group of roof beams being at the high level and the sections are of Castella form spaced at approximately 13 ft. 6 ins. centres to span between the latticed members and they in turn support 5 ins. and 6 ins. deep angle and channel purlins on which the decking is laid. The Castella sections are 15 ins. deep overall and are made from 10 ins. × 5 ins. R.S.J.

Such a roof, particularly with the glazing in the vertical faces gives a high level of natural lighting. Adequate ventilation is provided by positioning the ventilators appropriately on the high level portions of the roof. The heated air is speedily disposed of and the system lends itself to a wide range of ventilation requirements. Overall this construction has been found to be an economic answer to the problems associated with lighting and ventilation in structures of this type and the use of Castella sections enables spans up to 80 ft./100 ft. between main girders to be covered with a minimum of steel in the construction. Spans of extreme length such as those mentioned may not be desirable in many cases but the opportunity of covering such spans is afforded by this method if desired. The depth of the main latticed roof girders is of the order of 10 ft. 8ins. over booms and affords ample opportunity for the employment of vertical glazing despite the presence of a walkway adjacent to the foot of the glass for cleaning purposes. The wide " spread " of light from the glazed areas tends to counter the shielding effect of the walkway which is of course in open mesh steel.

The roof areas generally have a very low pitch, and this is provided by cranking the Castella roof beams at mid span, the high bays being cranked upward and the low bays downward at midspan to provide for the disposal of rainwater. Consequently the final drainage route of surface water is along the valley of each of the low roof areas. Further, a problem frequently encountered in steelworks buildings is that concerning the disposal of dust deposits on the roof cladding from other items of adjacent plant. In cases where this deposit is severe it may be advisable to employ a steel plate roof which will allow for the use of brooms, shovels, and barrows for the removal of the dust. However, in the case under consideration it was not anticipated that the dust level would be very considerable and the decking roof does permit of normal walking access and the use of brooms to clear away the material. Shovelling or barrowing of course cannot be allowed with this form of deck construction as it would in many cases injure the weatherproofing severely. Purlins on the 34 ft. 9 ins. span roof beams were used in this case to accommodate the span of the roof decking, but it is frequently possible to eliminate the use of purlins by adjusting the node points of the main roof girders so that the beams may be spaced at centres corresponding with the permitted span of the roof decking and consequently purlins may be eliminated.

In circumstances where it is not possible or not desirable to take rainwater discharge directly to the ground from the valleys in the low portions of a roof of this type, use may be made of a pressed steel gutter often of copper bearing steel and having a sole width of 2 ft. to 2ft. 6 ins. and a minimum depth of 6 ins. Such a gutter will adequately cater for a very large discharge of water and can also be used as an access and cleaning walkway as it is capable of spanning considerable distances without intermediate support. On those occasions where the gutter may form an outside eaves member, handrailing may be attached to the outer side of the gutter so that safety to personnel is provided, and in addition the tubular handrails at the top and in the centre may be arranged for the supply of water for cleaning purposes and in the case of lighting walkways inside the building the second handrail may be used as a conduit for electric wiring to the artificial lighting system. In respect of the glazing cleaning walkways on the strip mill buildings, these were placed on the inside of each bay and access to them is obtained from the low roof areas by means of doors suitably formed at the ends of the spans. Where process heat is not of such magnitude that large ventilators on the roof become necessary, the end spaces at the gables of the high portions may be filled with louvred ventilators and the opportunity is

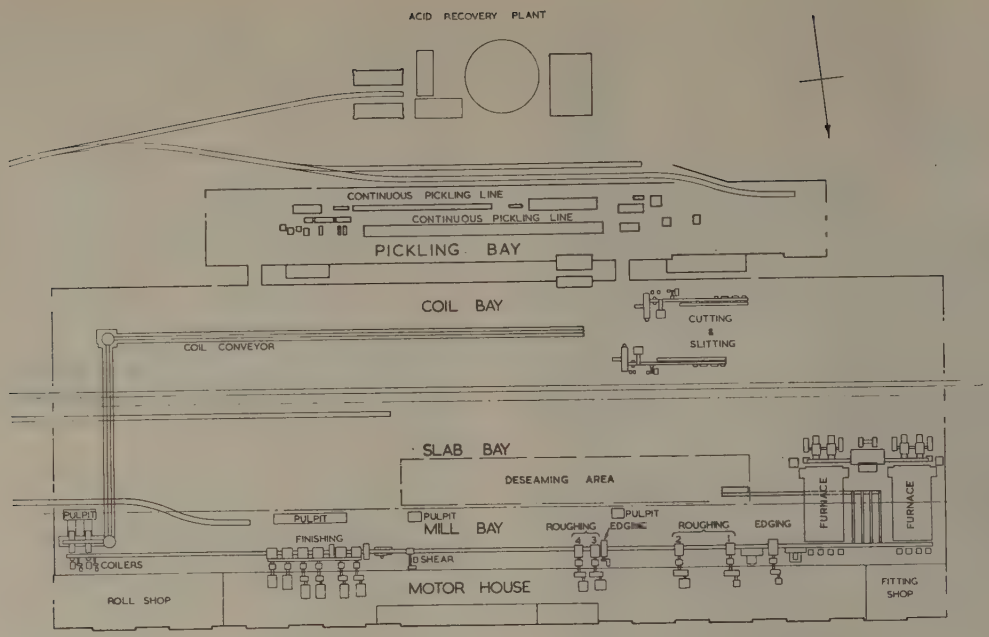

Fig. 15.—Brinsworth Mill—general layout

presented for addition to such ventilation by placing louvres to replace the end panels of vertical glazing. Generally the gable spaces are sheeted.

Castella beams

The problem of the economic treatment of large spans under light loading is considerably eased by the employment of these beams. In fact they provide a means of covering long spans either in the form of roof beams, windgirders, walkway supports, lighting galleries, pipe bridges, and vertical side framing members and in the case of this series of buildings even roof legs for the columns, with a minimum expenditure of material and workmanship and consequently provide an economic answer to these problems. This patented method of construction has in recent years achieved a tremendous popularity entirely on its merit as a structural system, and it is now used very widely in the industry for many purposes. Its efficiency under conditions such as those described above is reflected in the use of the system in many steelwork contracts where the improved characteristics of the section may be exploited.

Crane Girders

Crane girder design on steelworks superstructures in particular is a problem which must be solved upon the results from analysis of, and tests performed on actual girders in work. In addition special consideration should be given to the possible future requirements of the various bays in view of the fact that for many reasons in recent years the dead weights of cranes for a given lifting capacity have increased very considerably and the problem cannot be solved by the simplest approach. One of the most difficult assessments to make concerns the transverse loading on gantry girders from the cross travelling motion of the crab. It is possible to obtain empirical values for such loading from certain published specifications. However it is well known that in the case of steelworks plant operation these values for transverse surge loading are often exceeded. The design of the gantry girders in the buildings under consideration has been approached in this way and the transverse surge loading taken as 10 per cent of the weight of the crab plus the lifted load. This figure is generally applicable to average production cranes. Nevertheless in cases where grab cranes on long falls, or cranes carrying long length bars where pendulum action is a distinct possibility, the surge values required may be extended up to 30 per cent of the above summation.

All sections of gantry girders are proportioned so that they will resist all vertical and transverse forces which may be applied to them in work and walkways and the like which may be established at crane girder level are not considered to take an active part in the properties of the sections so designed. Walkways of this kind however can be taken into consideration as a lateral stiffening member enabling a higher unit permissible compressive stress to be used in the top flanges. All girders are designed as simple supported spans. Transverse surge loading is assumed to be taken entirely by the top flange of the girder. This approach results in an asymmetric section which by suitable adjustment of the flange dimensions produces a section of high efficiency. Crane girders are invariably manufactured in all welded construction which also tends to the production of an efficient section. In the case of girders up to 5 ft. deep, flat section web stiffeners are employed. Over this depth, it is usual to employ the half of a Castella channel or joist as stiffeners. This form of construction possesses a very high transverse inertia and can produce considerable economies in steel compared with flats for stiffener sections on deep girders.

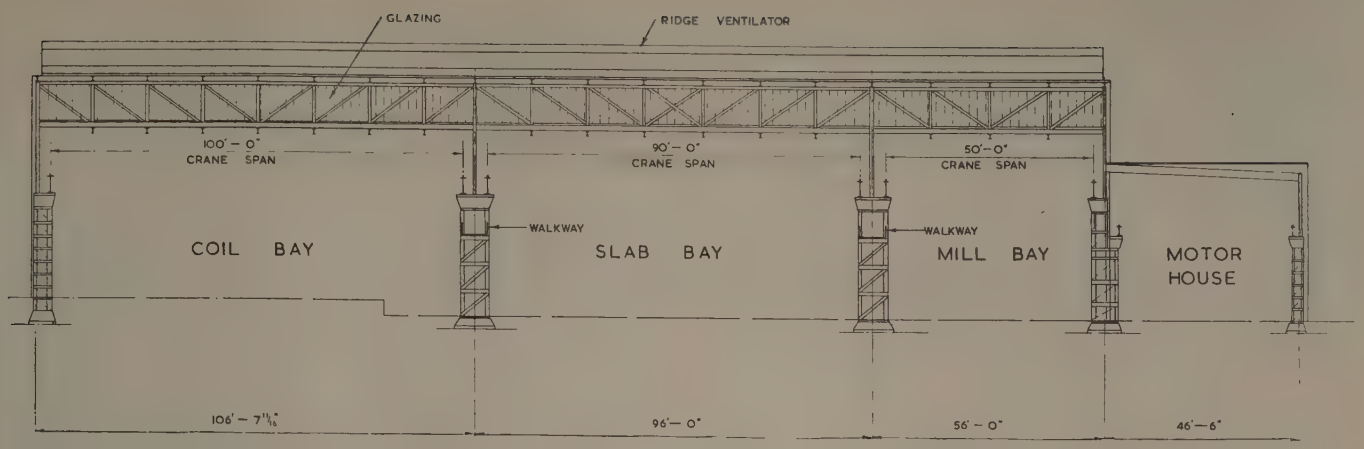

Fig. 16.—Sectional elevation of medium width hot strip mill building.

Consideration is given to track maintenance in respect of rail changing by the provision of suitable clips for the attachment of the crane rails. All rails are provided in lengths of approximately 60 ft. and are puddle welded at the joints, thereby eliminating the rail joint effect which is a common source of trouble on such gantries. This method has simplified rail changing very considerably and has proved to be completely satisfactory over a number of years. If the necessity should arise for the replacement of a length of rail such a change may be made very simply and quickly.

An important point in respect of crane gantries for use under arduous conditions is that lineability of the track must be maintained at all times. Therefore, arrangements should be made on the column caps and in the ends of the crane girders to allow for some lateral adjustment in lining up the girders after erection. The holding down bolts to the crane caps are in general unsuitable for the transmission of the forces concerned and this function may be taken over by stiff diaphragms between the bearing stiffeners of the crane girders and the flanges of the roof legs of the columns, or in cases where the gantry is in the open air and no roof leg is provided, a suitable bracket may be arranged to transmit the transverse loading and to fix the girders laterally. The diaphragms or brackets should be fixed by high strength friction grip bolts, or by welding at site. Welding between the top flanges and the webs is calculated on the basis of the vector sum of the gross end shear and the individual wheel load shear. Consequently the fillets between the web and the top flange are often of a different section from those connecting the web to the bottom flange.

High Strength Friction Grip Bolts

Increasing use is being made of these fasteners particularly as a replacement for site riveting or turned and fitted bolts. The capacity of this form of bolt is more than equal to the fastener which it replaces. It is not affected by vibration and is capable of accepting load in terms of shear or shear plus axially applied tension as may be encountered in crane girder brackets and moment connections in general. Site work, maintenance and erection of steelwork is considerably simplified in consequence. In cases where trouble is encountered in the older type of riveted crane girder where arduous service conditions have loosened flange plate rivets, replacement by high strength friction grip bolts has entirely eliminated the trouble and has in consequence reduced maintenance work to a very considerable degree. In fact it is difficult to imagine a situation in which a rivet or turned bolt can compare in efficiency with this up to date connector. Many connections in the strip mill buildings have been made with these bolts.

The notes presented above in respect of the steel frame construction are by no means comprehensive, but it is hoped that they will be of interest to those concerned with the design of steelworks superstructures in particular, and to many whose problems are not directly in this field of endeavour.

Book Review

International Association for Bridge and Structural Engineering Publications, Vol. XVIII, 1958. (Zurich : Verlag Leemann, 1959). 9½ in. × 6½ in. 296 + viii pp.

The eighteenth volume of " Publications " contains thirteen papers, of which nine are in English, three in French, and one in German, all the papers having titles and summaries in English, French and German.

Amongst the papers included in this volume are the following :— A method for analysing deformations of plane trusses, general instability of low framed buildings, the influence of residual stress on the carrying capacity of eccentrically loaded columns, calculation of prestressed concrete members according to the strain theory, stability of rib-reinforced cylindrical shells under lateral pressure, an experimental study on model continuous beam bridge with steel deck, cyclic loading of portal frames, and analysis of thin elastic shallow segmental shells.

Folded Plate Construction : An Investigation of Collapse Conditions*

by A. R. Dykes, B.Sc., A.M.I.Struct.E., A.M.I.C.E., A.R.C.S.T.

1. Synopsis

Stressed skin construction of the folded plate type is not used to any great extent in Great Britain, and one reason for this may be the lengthy calculations at present used in design. The paper anticipates the possibility of design on an ultimate load basis and describes an investigation into the collapse conditions of small roof structures in reinforced concrete.

A brief outline of the experimental work is given. The measured ultimate loads and collapse forms show good agreement with those obtained by theoretical analysis using the fracture line theory extended to include the effects of primary membrane forces.

2. Introduction

In the field of stressed skin construction, much attention has been directed towards cylindrical shells, and the roof structures known variously as Folded or Hipped Plates or Faltwerke have not been given the consideration they deserve. Where use has been made of this construction, design is approached from an elastic basis and may have a complexity which makes it less than satisfactory.

A method of design for reinforced concrete slabs based on the form in which they finally collapse has been gaining in popularity and is being widely used, particularly in the Scandinavian countries. This Yield Line or Fracture Line method was developed in Denmark by K. W. Johansen[1] and is now recognised in Great Britain by its inclusion in the recommendations of the 1957 revision of B.S. Code of Practice 114. The method gives a very simple and realistic approach to problems which have hitherto been solved after considerable mathematical labour or by the use of empirical methods all involving assumptions regarding the behaviour of the material which are not always borne out in practice.

No attempt appears to have been made to apply such ultimate load methods to folded plate structures and the Author was prompted to initiate an investigation along these lines using small reinforced concrete structures. The results of the preliminary work undertaken are sufficiently encouraging to suggest an extension of the range of study, and possible formulation of a design method.

A fundamental of the fracture line theory is the assumption of constant and uniform moment along all yield lines. This can hardly be true for reinforced concrete elements when excessively high rotations occur, as it is always possible that disintegration may take place along one fracture line before the formation of subsequent lines of rupture. The moment along this fracture line may therefore be indeterminate.

From theoretical considerations it can be shown that the value of the moment along the first fracture line may vary within wide limits with only a very small change in collapse form and load. Hence the basic assumption appears to be fully justified.

3. Range of Experimental Investigation

3.1 *Description of Test Structures*

A standard structure form was adopted and the conditions of support given to the structure were varied. This simple basic form, its dimensions and various edge conditions are illustrated in Fig. 1 and Fig. 2 in which edges simply supported and with rotational freedom are shown by single hatching and continuous edges by cross hatching on plan views of single slab elements.

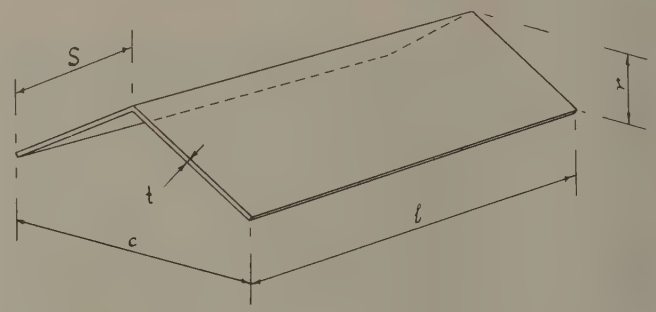

Fig. 1.

Span l	=	**29.50 ins.**
Chord c	=	**20.50 ins.**
Rise r	=	**6.80 ins.**
Slope length S	=	**12.30 ins.**
Thickness t	=	**0.50 ins.**

The models were made in cement mortar using river sand passing B.S. Sieve No.7 and ordinary Portland cement in the proportions 4 : 1 by weight. The water/cement ratio was dictated by workability requirements but remained sensibly constant throughout. Equal reinforcement in two directions at right angles was provided by a steel wire mesh placed in the middle surface of the concrete and giving a steel ratio of 1.3 per cent based on an effective concrete depth of 0.25 in.

Collapsible formwork of timber and aluminium sheet, used to support the wet mix, was withdrawn after hardening of the mortar, leaving the structure supported on tied edge beams of timber where it remained curing until transfer to the test frame.

* *Paper to be read before the Institution of Structural Engineers, at 11, Upper Belgrave Street, London, S.W.1., on Thursday, 25th February, 1960, at 6 p.m.*

[1] Johansen, K. W.: Doctorate Thesis, Tech. Univ. Denmark, 1943.

In all, eight models were made, one being used to assist in developing and testing of the loading device, and one collapsing prematurely. Thus six units were available for actual test purposes.

3.2 *Loading*

All structures were subjected to a symmetrical distribution of loads normal to the surfaces. Dead loads acting through a lever system gave concentrated loads, at 4 in. centres longitudinally and transversely, applied to the slab surface through distribution plates $2\frac{1}{2}$ in. square. The arrangement of these load points is shown in Fig. 3 and a structure of Type I under test is illustrated in Fig. 4. The error incurred by assuming this loading to be uniformly distributed is theoretically about 1 per cent.

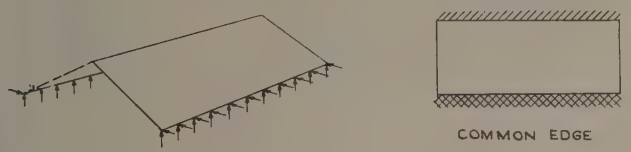

Fig. 2a.—Structure Type I Longitudinal Edge Supports

Fig. 2b.—Structure Type II End Traverse Supports

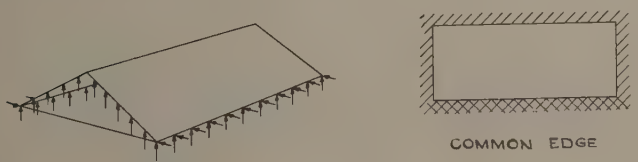

Fig. 2c.—Structure Type III Longitudinal Edge and End Traverse Supports

3.3 *Testing*

Two structures were tested under each support condition, dead loads being applied to the loading levers to give surface load increments of approximately 0·2 lb/in.^{2} until failure occurred. During loading, observations of general behaviour, formation of cracks, and deflections at selected points were noted.

Control beams having the same cross-sectional properties as the slab elements were loaded to destruction to give the values of ultimate moment and flexural rigidity for each series of test structures.

4. Experimental Results

Each of the two test structures in a set tested under the same conditions gave consistent crack patterns and similar collapse loads. The collapse form for one structure of each type is sketched in Fig. 5, and Fig. 6 illustrates the actual modes of collapse of the structures. To avoid complete destruction loading was stopped in some cases before the failure along the final fracture line had travelled through the section to cause crushing of the concrete on the compression side, so that only parts of the fracture lines are visible on the upper surface. Fig. 7 and 8 indicate the increase of deflection with load in each case.

In assessing the collapse loads for the structures, account was taken of self-weight and the weight of loading attachments.

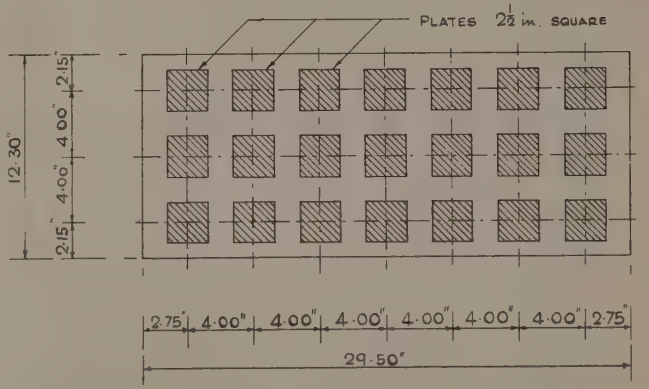

Fig. 3.—Location of Load Distribution Plates

TABLE A

STRUCTURE TYPE	MODEL	DISTANCE FROM EDGE TO LONG^{L} POS. FRACT. LINE (β in.)		DIST. FROM TRAVERSES TO INTERSECTION OF TRANS. FRACT. LINE WITH EDGE OR LONG^{L} POS. FRACT. LINE (x in.)		REL. NORM. DEFL^{N} AT LONG^{L} POS. FRACT. LINE (Δ in.)				COLLAPSE LOAD (w lb/in.^{2})				COLLAPSE LOAD ERROR % OF THEOR(i)
						THEORETICAL*			EXP.	THEORETICAL *			EXP.	
		THEOR.	EXP.	THEOR.	EXP.	(i)	(ii)	(iii)		(i)	(ii)	(iii)		
I	A	5.09	4.90	–	–	0.182	0.176	0.184	0.200	1.80	1.82	1.80	1.79	-0.6
	B	5.09	3.80	–	–	0.182	0.176	0.184	0.196	1.80	1.82	1.80	1.79	-0.6
II	A	-	-	8.39	9.25	-	-	-	-	1.11	-	-	1.23	+10.7
	B	-	-	8.39	8.00	-	-	-	-	1.11	-	-	1.04	-6.3
III	A	5.09	4.94	7.25	7.02	0.244	0.235	0.241	0.300	1.95	1.96	1.94	1.98	+1.5
	B	5.09	4.59	7.25	7.68	0.244	0.235	0.241	0.380	1.95	1.96	1.94	1.98	+1.5

* THEORETICAL VALUES ARE OBTAINED THUS :–

(i) TRIAL AND ERROR SOLUTION : SECTION 5.4

(ii) "APPROXIMATE" SOLUTION USING $T_e = \frac{\pi^2 EI}{\ell_e^2}$

(iii) "APPROXIMATE" SOLUTION USING $T_e = \frac{\pi^2 EI}{S^2}$: SECTION 5.6

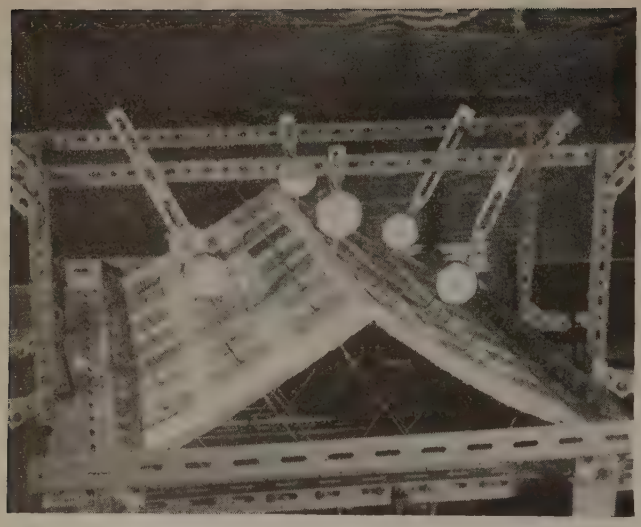

Fig. 4.—Structure Type I under Test

The experimental results are summarised in Table A for comparison with theoretical quantities.

The results of the control beam tests indicated a value of flexural rigidity EI of about 1900 lb.in.^{2} for all cases, compared with a calculated value of 2100 lb.in.^{2}. Since the expression for deflection Δ derived in Section 5.3 is not sensitive to changes in EI value within a fairly wide range a value of 2000 lb.in.^{2} has been adopted throughout.

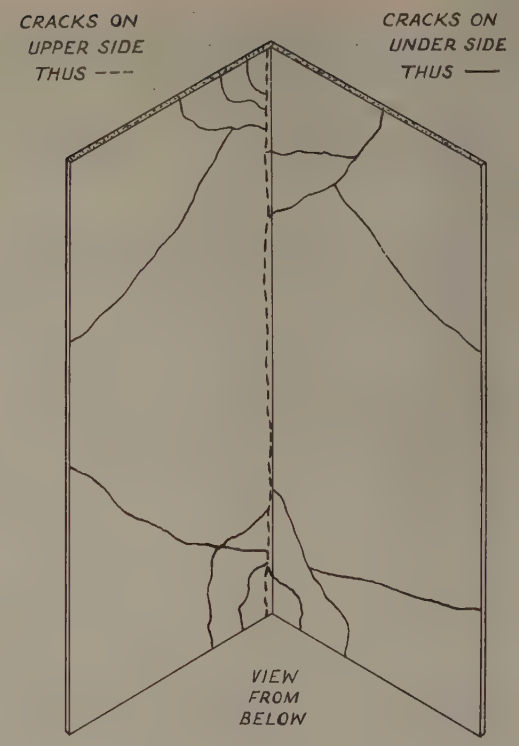

Fig. 5b.—Collapse Form of Structure IIA

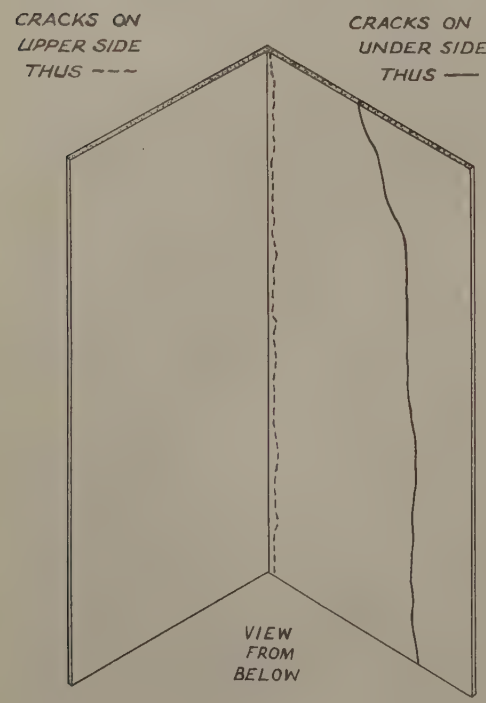

Fig. 5a.—Collapse Form of Structure IB

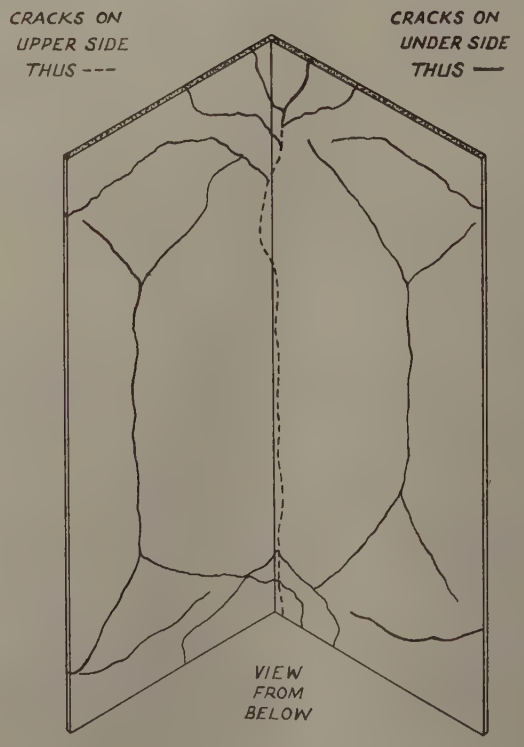

Fig. 5c.—Collapse Form of Structure IIIB

Fig. 6a.—Collapse of Structure IB

Fig. 6b.—Collapse of Structure IIA

5. Theoretical Investigation of Collapse Conditions

5.1 *Normal Surface Loads*

It may reasonably be assumed that for the type of structure investigated the first yield line will form along the common edge of the two slab elements forming the structure. This will hold for all support conditions because of the span/chord and rise/chord ratios employed. The symmetrical form and loading will allow consideration of one slab element with a constant moment acting on one edge and this procedure is adopted in the following treatment.

5.11 *Longitudinal Edge Supports—Structure Type I.*

The support conditions here are such that while the structure is not a true shell type it represents a move from simple slab towards stressed skin construction.

Fig. 6c.—Collapse of Structure IIIB

Referring to Fig. 9 (a),

At collapse, $F = \frac{wS}{2} - \frac{m}{S}$

$$M = \left(\frac{wS}{2} - \frac{m}{S}\right) \cdot s - \frac{ws^2}{2}$$

For maximum value of M at $s = p$,

$$\frac{dM}{dp} = \frac{wS}{2} - \frac{m}{S} - wp = 0$$

$$\text{and } p = \left(\frac{S}{2} - \frac{m}{wS}\right)$$

(i.e.) Second fracture line will form parallel to the supported edge and at distance $p = \left(\frac{S}{2} - \frac{m}{wS}\right)$ from the edge.

For virtual displacement δ at $s = p$, as in Fig. 9 (b),

$$m\left[\frac{\delta}{p} + 2.\frac{\delta}{S-p}\right] = wp\,\frac{\delta}{2} + w\,(S-p).\frac{\delta}{2}$$

Substitution of the value for p noted above leads to :

$$m^2 - 3wS^2.\,m + \frac{w^2}{4}.\,S^4 = 0$$

and $m = 0{\cdot}086wS^2$.

With $S = 12{\cdot}30$ in.,

$m = 13{\cdot}00\,w$ lb.in/in.; $p = 5{\cdot}09$ in.

$F = 5{\cdot}09\,w$ lb/in. ; $T = 10{\cdot}86\,w$ lb/in.

If the actual distribution of applied loads is considered, it will be found that $m = 13{\cdot}12\,w$ lb.in/in. and $p = 4{\cdot}90$ in., so that the assumption of uniformly distributed loading is justified.

5.12 *End Traverse Supports—Structure Type II.*

The structure form is here a shell type with free longitudinal edges. The crack pattern under uniform loading will be as shown in Fig. 10.

Fracture line theory gives equivalent corner shear forces $Q = m.\frac{x}{S}$, $\cdot$ indicating upwards, $+$ indicating downwards, in Fig. 10.

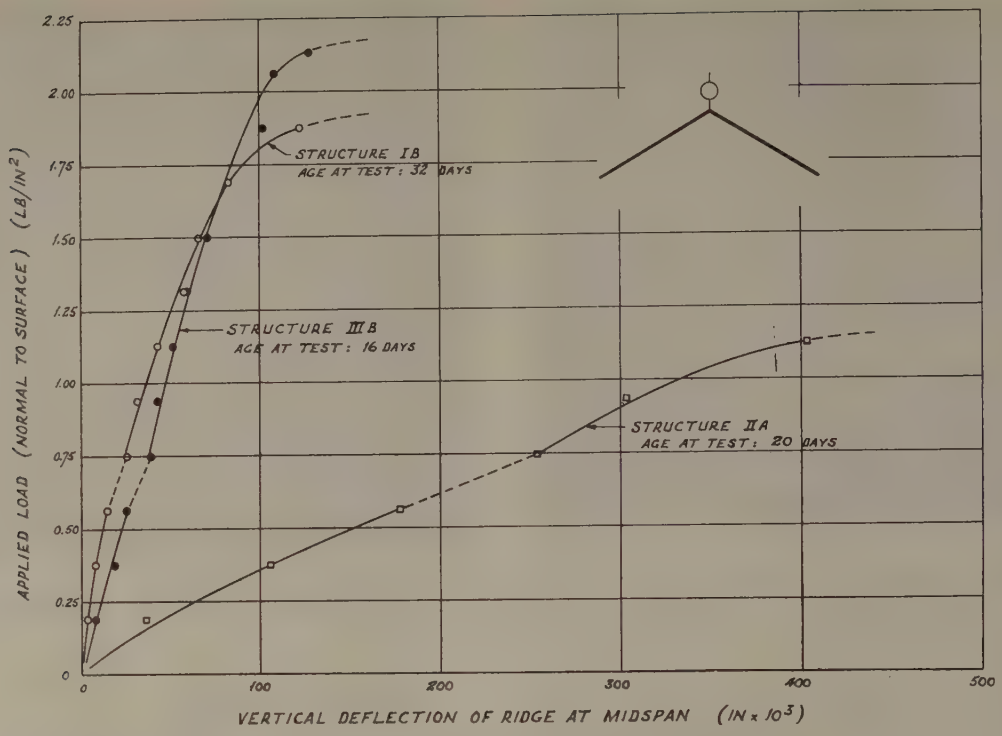

Fig. 7.—Load/Deflection Curves for Ridge

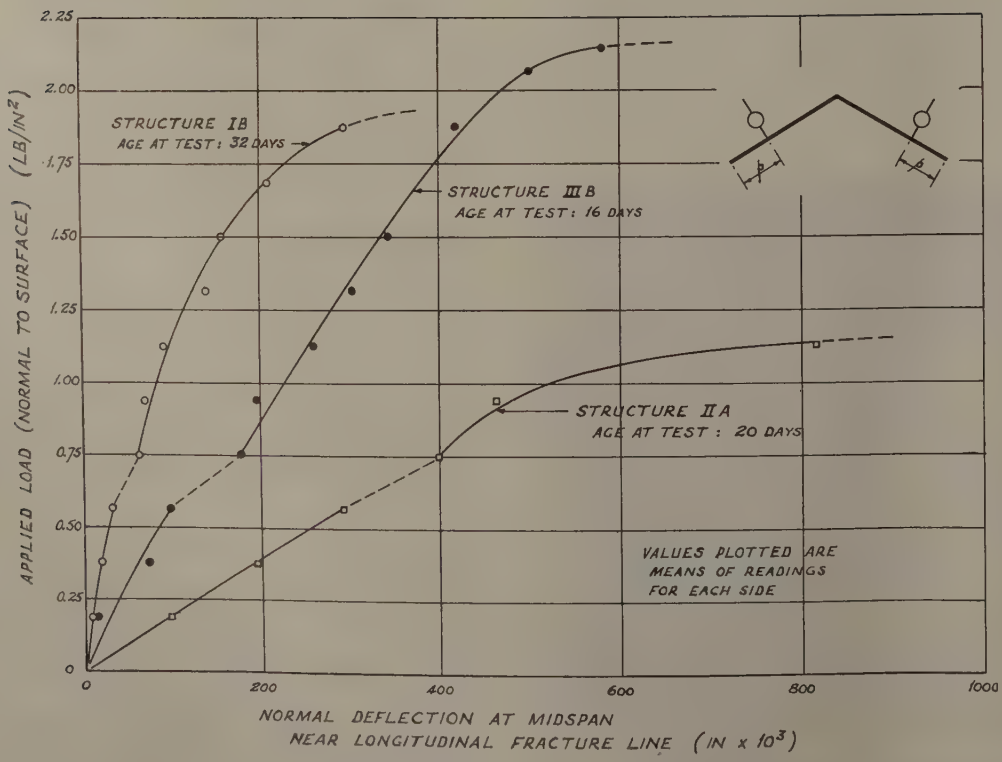

Fig. 8.—Load/Deflection Curves for Slab Elements

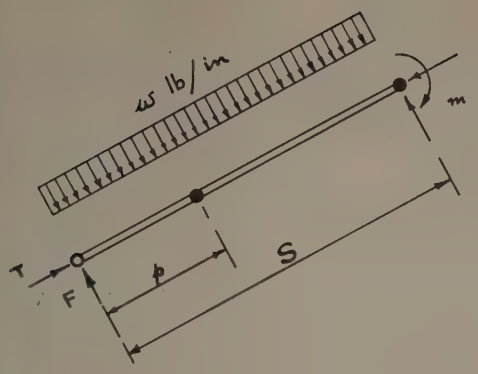

FIG. 9a.

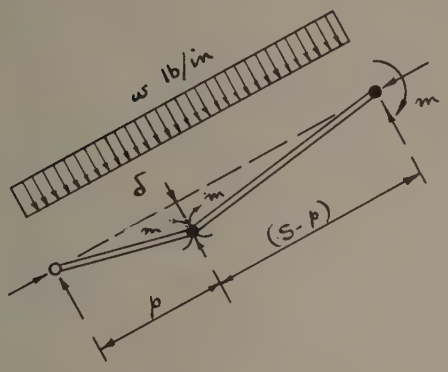

FIG. 9b.

If the Equilibrium Method of calculation is adopted these forces must be introduced. With this approach, too, either a trial and error solution, quite satisfactory for design purposes, or a longer algebraic procedure is necessary to determine distance x and moment m.

For an imposed displacement of $\delta = 1$ at the edge of slab part (2), the Equation of Virtual Work is :

$$m\left[\left(S \cdot \frac{1}{x}\right) \cdot 2 + \left(x \cdot \frac{1}{S}\right) \cdot 2 + \frac{l}{S}\right] = \frac{wSx}{6} \cdot 2 + \frac{wxS}{6} \cdot 2 + \frac{w(l-2x) \cdot S}{2}$$

$$\therefore \quad m = \frac{wS^2}{6}\left[\frac{3lx - 2x^2}{2x^2 + lx + 2S^2}\right]$$

For correct position of fracture lines, m is maximum.

$$\therefore \quad \frac{dM}{dx} = 0$$

Hence $x^2 + \frac{S^2}{l} \cdot x - \frac{3}{4} \cdot S^2 = 0$

$$\text{and } x = 0{\cdot}50\,\frac{S^2}{l}\left[\left\{1 + 3\left(\frac{l}{S}\right)^2\right\}^{\frac{1}{2}} - 1\right]$$

With $S = 12{\cdot}30$ in and $l = 29{\cdot}50$ in.

$x = 8{\cdot}39$ in ; $m = 21{\cdot}98\,w$ lb.in/in.

If a calculation is made using the actual distribution of loads, the difference in the value of m is of the negligible order of 2 per cent.

5.13 *Longitudinal Edge and End Traverse Supports—Structure Type III.*

This structure conforms to a shell with edge beams infinitely stiff in the horizontal and vertical planes but with negligible torsional rigidity.

The crack pattern to be expected is as sketched in Fig. 11.

A solution for distances x and p and moment m is most readily obtained in this case by the Equilibrium Method.

At the intersection of the positive fracture lines, equivalent corner shear forces have zero value.

Equilibrium conditions are :—

Part (1) : $m.S = \frac{wSx^2}{6} \quad \therefore \; m = \frac{wx^2}{6} \quad \cdot \quad \cdot \quad \cdot \quad (1)$

Part (2) : $m.l = \frac{wxp^2}{6} \cdot 2 + \frac{w(l-2x)\,p^2}{2}$

$$\therefore \; m = \frac{wp^2}{6l}\,(3l - 4x) \quad \cdot \quad (2)$$

Part (3) : $(m.l)2 = \frac{wx(S-p)^2}{6} \cdot 2 + \frac{w(l-2x)\,(S-p)^2}{2}$

$$\therefore \; m = \frac{w(S-p)^2}{12 \cdot l} \cdot (3l - 4x) \quad (3)$$

From (2) and (3), $p^2 = \frac{(S-p)^2}{2}$

$$\therefore \; p = \frac{S}{1+\sqrt{2}}$$

From (1) and (3),

$$x^2 + 0{\cdot}687\,\frac{S^2}{l} - 0{\cdot}515\,S^2 = 0$$

$$\text{and } x = 0{\cdot}3435\,\frac{S^2}{l}\left[\left\{1 + 4{\cdot}36\left(\frac{l}{S}\right)^2\right\}^{\frac{1}{2}} - 1\right]$$

With $S = 12{\cdot}30$ in. and $l = 29{\cdot}50$ in.

$p = 5{\cdot}09$ in. ; $x = 7{\cdot}23$ in. ; $m = 8{\cdot}74w$ lb.in/in.

The correspondence between this value of p and that obtained for Structure Type I should be noted.

For Structure Type III the force actions at a midspan section are :

$$F = 5{\cdot}44\,w \text{ lb/in.} \; ; \; T = 10{\cdot}34\,w \text{ lb/in.}$$

Again the error introduced by assuming a uniform distribution of load is of a small order.

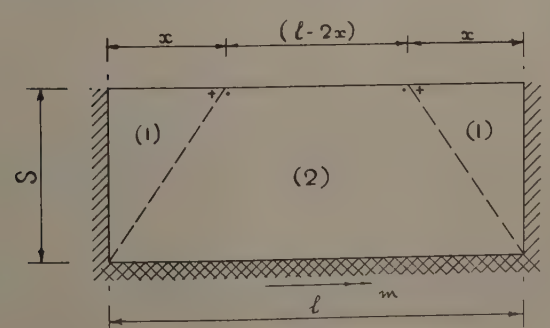

Fig. 10.

Theoretical Crack Pattern for Structure. Type II

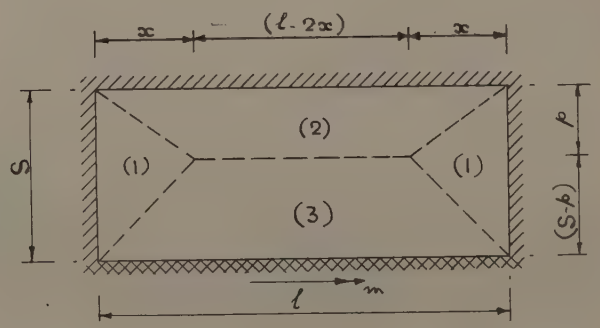

Fig. 11.

Theoretical Crack Pattern for Structure. Type III

5.2 *Membrane Forces.*

Forces acting in the plane of a slab element may materially affect the ultimate load capacity of the structure. Primarily this capacity will be affected either by increased direct compression or by additional moments produced by eccentricity, due to slab deflection, of edge compressive or tensile forces.

Where opposite edges of the slab elements are not restrained against movement in the plane of the slab, (e.g.) in Structure Type II, the effects of membrane forces are likely to be small and for a first approximation may be safely ignored. However if the opposite edges are restrained against such movement, (e.g.) by attachment to other slab elements or edge beams, as in Structure Types I and III, consideration should be given to the effects of edge forces. The flexibility of the thin slabs results in relatively large deflections as the collapse load is approached, and the direct compression effect is small and negligible compared with the additional moment due to deflection.

The edge compressive forces will not materially affect the position of the fracture lines but in Structure Types I and III the longitudinal positive fracture line will form when the yield moment is reached by a combination of lateral bending due to surface loads and buckling due to edge thrusts.

In Structure Type I, thrust T due to translational restraint at the edge will produce an increase in bending moment $= T.\Delta$ lb.in/in. where Δ is the eccentricity of T at the location of the fracture line just before collapse.

In Structure Type III, as long as the ratio $\frac{l}{S} > 0{\cdot}83$, the position of the longitudinal fracture line is the same as in Type I. Hence at midspan the additional bending moment $= T.\Delta$ lb.in/in.

It now becomes necessary to determine the value of deflection Δ.

5.3 *Deflection of Slab Element.*

Deflections of the slab element can be calculated using the theory of elasticity until the formation of the second fracture line at distance p from the edge.

Referring to Fig.9(a),

$$EI\frac{d^2y}{ds^2} = -\mathrm{M} = -F.s + \frac{ws^2}{2} - T.y$$

$$\therefore \quad \frac{d^2y}{ds^2} + \alpha y = \beta.\, s^2 - \gamma.\, s$$

$$\text{where } \alpha = \frac{T}{EI} \quad \beta = \frac{w}{2EI} \quad \gamma = \frac{F}{EI}$$

The solution to this equation is :

$$y = \frac{2\beta}{\alpha}.\cos s\sqrt{\alpha} + \left[\left(\frac{2\beta}{\alpha^2} + \frac{\gamma S}{\alpha} - \frac{\beta S^2}{\alpha} - \frac{2\beta}{\alpha^2}.\,ocs\, S\sqrt{\alpha}\right) cosec\, S\sqrt{\alpha}.\, sin\, s\sqrt{\alpha}\right] + \frac{\beta}{\alpha}s^2 - \frac{\gamma}{\alpha}s - \frac{2\beta}{\alpha^2}$$

At longitudinal positive fracture line,

$$s = p \text{ and } y = \Delta.$$

Hence :

$$\Delta = \frac{wEI}{T^2}\left[\cos p\sqrt{\frac{T}{EI}} + \left\{\left(1 - \frac{mT}{wEI} - \cos S\sqrt{\frac{T}{EI}}\right) cosec\, S\sqrt{\frac{T}{EI}}.\, sin\, p\sqrt{\frac{T}{EI}}\right\} + \frac{pT}{EI}\left(\frac{p}{2} - \frac{F}{w}\right) - 1\right]$$

5.31 *Theoretical Deflections.*

Substituting in the equation above the values for T, F, p and m determined in Sections 5.11 and 5.13 and 2,000 lb.in.^{2} for EI, the following expressions are obtained.

Structure Type I. :

$$\Delta = \frac{16{\cdot}97}{w}\left[\cos 0{\cdot}375\sqrt{w} + \left\{(1 - 0{\cdot}0706w - \cos 0{\cdot}9065\sqrt{w})\, cosec\, 0{\cdot}9065\sqrt{w}.\, sin\, 0{\cdot}375\sqrt{w}\right\} - 0{\cdot}0706w - 1\right]$$

Structure Type III :

$$\Delta = \frac{18{\cdot}69}{w}\left[\cos 0{\cdot}366\sqrt{w} + \left\{(1 - 0{\cdot}0452w - \cos 0{\cdot}885\sqrt{w})\, cosec\, 0{\cdot}885\sqrt{w}.\, sin\, 0{\cdot}366\sqrt{w}\right\} - 0{\cdot}0762w - 1\right]$$

5.4 *Evaluation of Theoretical Collapse Loads*

The general equation is : $m + T.\Delta = m_y$ where m_y is the ultimate strength of the section.

This ultimate strength will normally be calculated from concrete cube strength, steel yield stress, and section dimensions. For the purposes of this project the values of m_y used are those obtained from the control beam tests noted in Section 3.3.

Where $T.\Delta$ has a significant value as discussed in Section 5.2, trial and error solution of the deflection and moments equations is necessary to determine the collapse load.

5.41 *Structure Type I* : $m_y = 26{\cdot}90$ lb.in/in.

Trial Solution : $w = 1{\cdot}80$ lb/in.^{2} gives $\Delta = 0{\cdot}182$ in.

$$13{\cdot}00\, w + (10{\cdot}86\, w)\,(0{\cdot}182) = 26{\cdot}90$$

$$\therefore\ w = 1{\cdot}80 \text{ lb/in.}^2$$

Hence Collapse Load $= 1{\cdot}80$ lb/in.^{2}

5.42 *Structure Type II* : $m_y = 24{\cdot}45$ lb.in/in.

$$21{\cdot}98\, w = 24{\cdot}45$$

Hence Collapse Load $= 1{\cdot}11$ lb/in.^{2}

5.43 *Structure Type III* : $m_y = 21{\cdot}88$ lb.in/in.

Trial Solution : $w = 1{\cdot}95$ lb/in^2. gives $\Delta = 0{\cdot}244$ in.

$$8{\cdot}74w + (10{\cdot}34\, w)\,(0{\cdot}244) = 21{\cdot}88$$

$$\therefore\ w = 1{\cdot}95 \text{ lb/in.}^2$$

Hence Collapse Load $= 1{\cdot}95$ lb/in.^{2}

5.44 *Direct Compression Effects*

Inspection of the relative values of bending moment and " membrane " direct compression confirms that the latter may be neglected with the introduction of a small error only.

5.5 *Approximation to Deflections and Collapse Loads for Structure Types I and III*

A less laborious evaluation of the collapse load follows the use of the Perry type approximation for deflection calculation. This assumes that the deflection due to lateral bending is amplified by the end thrusts in proportion to a factor $z = \frac{1}{1-\mu}$ where $\mu = \frac{T}{T_e}$, T_e being the Euler load.

For deflection due to bending caused by lateral loads only,

$$EI\frac{d^2y}{ds^2} = -F.s + \frac{ws^2}{2}$$

With zero deflection at $s = O$ and $s = S$, the solution is : $EI_y = \frac{F}{6}\left\{S^2.s - s^3\right\} - \frac{w}{24}\left\{S^3.s - s^4\right\}$

At the longitudinal positive fracture line in the structures considered, $y = \delta$ at $s = p = 0{\cdot}414S$; and $F = k.S.w$

Hence $EI\ \delta = wS^4\left\{0{\cdot}0572k - 0{\cdot}0161\right\}$

With $EI = 2000$ lb.in^2/in. and $S = 12{\cdot}30$ in.

$$\delta = 11{\cdot}435w\left\{0{\cdot}0572\,k - 0{\cdot}0161\right\}$$

Structure Type I :

$k = 0{\cdot}414 \qquad \therefore\ \delta = 0{\cdot}0867w$ in.

Structure Type III :

$k = 0{\cdot}442 \qquad \therefore\ \delta = 0{\cdot}105w$ in.

5.51 *Amplification Factor*

In the determination of this factor use is made of the Euler load $T_e = \frac{\pi^2\ EI}{l_e^2}$ where l_e is the effective length. This effective length will be something less than the actual length but the error incurred by using the actual length is very small and on the safe side.

Hence $T_e = \frac{\pi^2\ EI}{S^2} = 130{\cdot}6$ lb./in. ;

$$z = \left[\frac{1}{1 - T/130{\cdot}6}\right]$$

5.6 *Total Deflections and Collapse Loads*

When the " amplified " deflection (in terms of w) is known, the general equation : $m + T.\ \Delta = m_y$ can be set up. This results in a quadratic from which w can be obtained, with subsequent calculation of Δ.

5.61 *Structure Type I* :

$m = 13{\cdot}00\ w$ lb.in/in. ; $\quad T = 10{\cdot}86w$ lb./in. ;

$m_y = 26{\cdot}90$ lb.in/in.

$$z = \left[\frac{1}{1 - \frac{10{\cdot}86w}{130{\cdot}6}}\right] \qquad \therefore\ \Delta = \left[\frac{0{\cdot}0867w}{1 - 0{\cdot}0832w}\right]$$

$$\therefore\ 13{\cdot}00w + 10{\cdot}86w\left[\frac{0{\cdot}0867w}{1 - 0{\cdot}0832w}\right] = 26{\cdot}90$$

From which $w = 1{\cdot}80$ lb./in.^{2} and $\Delta = 0{\cdot}184$ in.

5.62 *Structure Type III* :

$m = 8{\cdot}74w$ lb.in/in. ; $\quad T = 10{\cdot}34w$ lb./in. ;

$m_y = 21{\cdot}88$ lb.in/in.

$$z = \left[\frac{1}{1 - \frac{10{\cdot}34w}{130{\cdot}6}}\right] \qquad \therefore\ \Delta = \left[\frac{0{\cdot}105w}{1 - 0{\cdot}0793w}\right]$$

$$\therefore\ 8{\cdot}74w + 10{\cdot}34w\left[\frac{0{\cdot}105w}{1 - 0{\cdot}0793w}\right] = 21{\cdot}88$$

From which $w = 1{\cdot}94$ lb/in.^{2} and $\Delta = 0{\cdot}241$ in.

These values of collapse loads and deflections calculated in a simple way differ only slightly from those obtained by the much more tedious trial and error solution used earlier.

6. Comparison of Experimental and Theoretical Results

The results of this investigation are summarised in Table A and show that, although the range is restricted, the measure of agreement between theory and experiment is remarkable for tests which were intended to be mainly exploratory in nature, no high degree of control being exercised. The theoretical approach is in a simplified form, no account being taken of secondary effects.

Considerable cracking across the corners of the structures of Types II and III is attributed to diagonal tension, against which the slab elements were not specially reinforced, and not to the corner effects investigated by Johansen.

In all tests, rupture lines were well defined and conformed to the predicted pattern. At failure of Structure Type III, secondary curved fracture lines were observed at each end of the slabs. These may be due to membrane tensions acting between the central area and a stiffening edge zone, and require further investigation.

At an early stage in the loading of each structure, a marked increase in deflections occurred suddenly. This stage is indicated by broken lines in Fig. 7 and 8, and appeared to coincide with the development of first cracks in the cement mortar, resulting in a change in effective section from plain mortar of full slab thickness to a " reinforced section " of effective depth equal to half slab thickness.

The divergence between theoretical and experimental deflections is less than might be expected in view of the nature of the material, the assumptions made in the theoretical calculations, and the difficulty of observing the deflections corresponding to the formation of the final fracture line.

As expected, the deflections of Structure Types I and III were of the same order and considerably less than those of Structure Type II. In examining Fig. 7 and 8 in this respect it should be remembered that the age at test was different for the different types. This is the reason for the deflection of Type III apparently being greater than Type I.

The collapse load for the Structure Type II is much less than for the other types and this together with the large deflections confirms that shell forms with unstiffened edges are seldom the most acceptable.

7. Conclusions

For the type of construction investigated, in which bending moments predominate, the fracture line theory gives a simple means of predicting collapse form and ultimate load. Use of an " approximate " method for deflection calculations is satisfactory, and is to be preferred on account of the easier solution obtained. The predicted values are in close agreement with those obtained experimentally.

The experimental technique adopted in the investigation gave satisfactory results and requires modification in only a few minor points affecting the loading device These modifications have been introduced for further work in hand, similar to that described above but extended to cover different structure forms and support conditions.

The theoretical treatment appears capable of extension to cover more complex cases and, if desired, secondary effects may be considered with little increase in mathematical labour.

8. Acknowledgments

The work described in this paper was carried out in the Structures Laboratory of the Royal College of Science and Technology, Glasgow, and the Author is grateful for the facilities made available.

His thanks are also due to Mr. R. Khanna, of Jabalpur, India, who as a post-graduate student was intimately concerned in the investigation.

Institution Notices and Proceedings

ORDINARY GENERAL MEETING

An Ordinary General Meeting of the Institution of Structural Engineers was held at 11, Upper Belgrave Street, London, S.W.1., on Thursday, 17th December, 1959, at 5 p.m. Mr. Lewis E. Kent, B.Sc., M.I.Struct.E., M.I.C.E., (President) in the Chair.

The following members were elected in accordance with the Bye-Laws. Will members kindly note that the elections, as tabulated below, should be referred to when consulting the Year Book for evidence of membership.

Students

Al-Jibbouri, Adnan Hamodi Khamas, of Portsmouth.
Baxendale, Robert, of Bolton, Lancashire.
Bharj, Santokh Singh, of Kingston, Surrey.
Burzelman, Clive Henry Sinclair, of Cape Town, South Africa.
Chia Soo Keok, of London.
Fish, Raymond, of Blackburn, Lancashire.
Fletcher, Martin Richard, of Sutton Coldfield, Warwickshire.
Griffin, John, of Bolton, Lancashire.
Harradine, Alexander Edward, of London.
Kent, Dennis William, of Bradford.
Loe Weng Wah, of Singapore.
Miles, Trenly Victor, of Salisbury, Southern Rhodesia.
Miller, Roy James, of Bolton, Lancashire.
Oseni, Festus Alfred Oladimeji, of Belfast.
Robinson, Michael Douglas, of Chester.
Stringer, John Andrew, of Chalfont St. Peter, Buckinghamshire.
Webb, Graham Charles, of Sanderstead, Surrey.
Basu, Amiya Kumar, B.E., of Croydon, Surrey.
Boxall, William Derek, B.Eng., of Wirral, Cheshire.
Burchess, David Sydney, of Bromley, Kent.
Bryan, Hugh, of Westerham, Kent.
Castleman, Maurice, of Sanderstead, Surrey.
Caton, John, B.Sc., of Blackburn, Lancashire.
Chatarjea, Sukhendu, B.E., of Calcutta, India.
Chopra, Ramesh Chandra, B.Eng., of Calcutta, India.
Collins, Terence Roy, of London.
Das, Suniti Bhusan, B.Eng., of London.
De Souza, Clarence Anthony, of Stockton-on-Tees, Co. Durham.
Fletcher, Bernard George, of Upper Belvedere, Kent.
Ganapathy, Ramalingam, B.Sc., of Bombay, India.
Ghoshal, Amitabha, B.Eng., of Calcutta, India.
Greig, Peter John, of Barking, Essex.
Harris, Ian Roy, of Brentwood, Essex.
Hill, Kenneth Brian, of Heston, Middlesex.
Holt, Eric John, of Enfield, Middlesex.
Horvath, Alfred, of London.
Karnik, Arun Balkrishna, B.E., B.Sc., of Bombay, India.
Lacey, Brian George, of London.
Lee Tong Yew, of Johore, Malaya.
Lockhart, Ronald Henry, of Glasgow.
Manohar, Sharad Narayan, M.Sc., B.E., of London.
Nicholls, Michael George, of London.
Odell, Jack Stewart, of London.
Perry, Ronald, B.E., of London.
Sibley, Ronald James, of Southampton.
Soyannwo, Olusola Sofoluwe, of London.
Stabholz, Albert, B.Sc., of London.
Steedman, James Cyril, of Brighton, Sussex.
Swindale, Cyril Ernest, of London.
Tate, Geoffrey Michael, of Sheffield.
Taylor-Lewis, Sylvanus Eliasaph Abosede, B.Sc., of Birmingham.
Turner, James Albert, B.A., of Leicester.
Walker, Geoffrey Charles, of Tamworth, Staffordshire.
White, Geoffrey Frederick John, of London.
Yates, Peter, of York.
Zekaria, Isaac Ezra, M.Sc., of London.

Associate-Member

Burrows, John Humphrey, M.A., of London.

Members

Bell, Lt. Col. Marcus Ernest Francis, M.B.E., of Sutton, Surrey.
Roderick, Professor Jack William, M.Sc., Ph.D., M.A., A.M.I.C.E., of Sydney, Australia.
Scott, William Richard, A.M.I.C.E., of London.

Transfers

Students to Graduates

Chesterton, Charles John, of Chesham, Buckinghamshire.
Hopkins, Kenneth, of Bridgend, Glamorganshire.
Pearson, Donald Lindsay, of Cheam, Surrey.
Rigby, Francis Robert, of Liverpool.
Rossington, Antony Bevan, of Culcheth, Lancashire.
Turner, John, of Haughton, nr. Timporley, Cheshire.
Yap Lim Sen, of Kuala Lumpur, Malaya.

Graduates to Associate-Members

Arnold, Brian Alfred, of Manchester
Brum, John Edward, of London.
Folly, Eric John, of Johannesburg, South Africa.
Hancock, John William, of Birmingham.
Henderson, Keith, of South Croydon, Surrey.
Higson-Smith, David John, of Salisbury, Southern Rhodesia.
Huang Wei-Liang, Joseph, B.Sc., of Birkenhead, Cheshire.
Korbusz, Tadeusz, of London.
McCormack, Alan Henry, of Manchester.
Mattis, Oswald Canute, of Kingston, Jamaica.
Mehta, Dulerai Amritlal, B.Eng., of Bombay, India.
Mookerjee, Malay Kumar, B.E., of Calcutta, India.
Pause, Dieter Ingo Wolfgang, B.Sc., of Salisbury, Southern Rhodesia.
Sim Bee Teck, of Singapore.
Wheelock, Colin, of Poynton, nr. Stockport, Cheshire.
Wild, John Patrick, B.Sc., of Grenoside, nr. Sheffield, Yorkshire.

Associate-Members to Members

Butters, Edward Albert, A.M.I.C.E., of London.
Gates, Major Ronald Henry Charles, R.E., M.C., of Bracknell, Berkshire.
Gurney, John Malcolm Okey, of Wargrave, Berkshire.
Neile, Sydney, of Northwich, Cheshire.
Poozeshi, Mahmood, of Tehran, Iran.

Associate-Members to Retired Associate-Members

Chisnall, Wallace Francis, of London.
Haslam, Wilfrid Thomas, F.R.I.B.A., of Myrtle Bank, via Parkside, South Australia.
Mabey, Thomas, of London.
Pallister, John Walton, M.I.C.E., of Jersey, Channel Islands.

PEARCE, Harold Ellis Dallas, M.C., B.Sc.(Hons.), A.M.I.C.E., of Wantage, Berkshire.
SEYMOUR, Charles Alfred, of London.

Associates to Retired Associates

HART DYKE, Ashley Francis, of Bathurst, Eastern Cape Province, South Africa.
HOWARTH, Lt. Col. Herbert Sutcliffe, of Thames, New Zealand.
ROWLANDS, Herbert Vincent, of Broadstairs, Kent.
WHITTAKER, Allen George Barry, F.R.I.C.S., of St. Mary's, Isles of Scilly.

Members to Retired Members

BOWLES, Reginald Ewart, M.Sc.Tech., of Heswall, Cheshire.
BOXALL, Cecil James Dimmock, M.Eng., A.M.I.Mech.E. of Bath.
BROUGHTON, Arthur Charles, M.I.Mech.E., of Worthing, Sussex.
CROWTHER, Fred Sefton, of Stafford.
DONE, Bertram, B.Sc., A.M.I.C.E., of Wilmslow, Cheshire.
FORREST, Capt. Hubert, M.C., A.M.I.Mech.E., of Mombasa, Kenya.
FROST, Albert Frederick Joseph, A.M.I.Mech.E., of Beaconsfield, Buckinghamshire.
GREGORY, Major Norman, B.Eng., of Cranleigh, Surrey.
HOWL, Frederick William, of Shenton Park, Western Australia.
LONG, Frederick Alan, A.R.I.C.S., M.I.Mun.E., of Downend, nr. Bristol.
MILLS, George Elliott, of Auckland, New Zealand.

OBITUARY

The Council regret to announce the deaths of Thomas Edward RAINE (Member); Ranjit Mohan CHATTERJEE, Patrick Joseph DOWNIE (Associate-Members).

RESIGNATIONS

Notification was given that the Council had accepted with regret the resignations of William Herbert BATEMAN, Major Henry Pownall DALLOW, Arthur Allison FORDHAM, John Ernest HUGHES, Joseph William PARTRIDGE, Reginald Frank REYNOLDS, Harold Percy SMITH (Members); Fred GREENHALGH, Harold Thomas HAYNE, P. LONAPPAN, Kenneth Outram MORLEY, Babu MUZUMDAR, James Richard OAKEY, Louis RUMBAK, Sommataya SUKHYANGA (Associate-Members); George BASS, William Charles MORGAN (Retired Associate-Members); Albert Edward ATKINS, Douglas Henry BANKS, Jack James CHESTERMAN, Harold George CLAPHAM, Pravinchandra Hiralal DOSHI, James Gordon ELDRIDGE, Esli James FORREST, Emory Leland KEMP, James Barry KIRBY, Harold LANE, Harold Snowden LANYON, Kenneth Piers LEAKE, Pieter Botha LOEDOLFF, Bernard MCMAHON, Salvadurai MAHALINGAM, Manas Kumar MANDAL, Kazimierz MONETA, Kenneth Alwyn OWENS, Derek Thomas PREECE, Peshotan Jivanji TARAPOREVALA, THEAN LIP THONG, Ian Edward TWADDLE, Hosagrahar Chandrasekharaiya VISVESVARAYA, Barry WARMISHAM, Herbert Hendrick WELBORN, John Frederick WHALE, Walter John Digby WRAGG (Graduates); Graham George COOKE, Frederick Hugo GARLICK, James GERRARD, Taze Wilson LAMB, Anthony James Bryan MCCARTHY, Robert Victor SPROULE, Joseph Abraham THUMPASSERY (Students).

INSTITUTION AWARDS

The following awards have been made for papers read before the Institution and at the Branches during the Session 1958-59 :—

London (Headquarters) Prize

Mr. F. R. Bullen, for a paper, "Extensions to Constructional Shop; 170 feet and other long spans."

Lancashire and Cheshire Branch

Mr. W. S. Watts, for a paper, "Some Points of Structural Interest at Calder Hall 'A' Nuclear Power Station."

Northern Counties Branch

Mr. W. H. G. Durose (posthumously), for a paper "The Relationship between Contractors and their Clients."

Mr. S. Barlow, for a paper "Universal Beams and their Application."

Northern Ireland Branch

Mr. J. C. McClure, for a paper "Report on the Third International Congress on Prestressing, Berlin, May, 1958."

Mr. J. G. Berry, "Prestressed Concrete Construction in Northern Ireland."

Scottish Branch

Mr. A. R. Dykes, for a paper "Field Investigation of Some Engineering Structures."

Mr. E. H. Cooley, "A Survey of Recent Concrete Work in Scotland."

Wales and Monmouthshire Branch

Mr. A. G. Thompson, for a paper "Modern Concrete Buildings."

Western Counties Branch

Mr. Derek Bond, for a paper "Design, Model Analysis and Testing of an 83 ft. Span Interconnected Portal Grillage."

RESEARCH AWARD

The Council have awarded a Research Medal to Professor A. G. Quarrell for a paper "Structures—the impact of modern metallurgy" which he read before the Institution on the 12th February, 1959.

DRURY MEDAL AWARD, 1959

The Council have awarded the Drury Medal for 1959 to Mr. D. W. Hunt, of Earlsfield, S.W.18.

The Competition is held biennially and the alternative subjects set for this, the seventh competition, were the design of a footbridge to be built over a new by-pass motorway and the design of a service reservoir of 1 million gallons capacity. Mr. Hunt chose the former subject.

Mr. A. D. Cox, of Northfield, Birmingham, who also submitted the design of a footbridge, was highly commended.

JOURNAL CASES AND BINDING, 1959

A binding case can be supplied for the twelve issues of the Journal, January-December, 1959 (Volume 37), price 12s. 6d. including postage. The price for binding in half-leather, inclusive of packing and postage, is 31s. 0d. per volume.

It is requested that all parcels containing Journals forwarded for binding should bear the name and address of the sender and must be despatched to reach the Institution by the 30th April, 1960.

An index will be included in all bound volumes.

Members making their own arrangements for binding may obtain a copy of the Index upon application to the Secretary.

THE MAITLAND LECTURE COMPETITION

A competition will be held for the Maitland Lecture which will be given during the Session 1960-61. Members and Associate-Members of the Institution are invited to submit a written lecture, the subject of which may be on research, design or construction in the field of structural engineering, with special reference to new developments.

The winner of the Competition will be awarded the Maitland Silver Medal and Premium (value £100).

Lectures submitted for the Competition must be received by the Institution not later than the 31st March, 1960. Further information regarding the conditions of the Award may be obtained on application to the Secretary.

EXAMINATIONS, JULY 1960

The Examinations of the Institution will next be held in the United Kingdom and overseas on Tuesday and Wednesday, July 12th and 13th, 1960 (Graduateship) and Thursday and Friday, July 14th and 15th, 1960 (Associate-Membership).

FORTHCOMING MEETINGS

The following meetings will be held at 11, Upper Belgrave Street, London, S.W.1.

Thursday, 11th February, 1960

Ordinary Meeting at 6 p.m., when a paper on "Brinsworth Steel Strip Mill" will be given in two parts, Part I by Mr. Donovan H. Lee, B.Sc.(Eng.), M.I.Struct.E., M.I.C.E., M.I.Mech.E., (Member of Council), and Mr. G. O. Kee, B.Sc., A.M.I.C.E., and Part II by Mr. N. Lancaster.

Thursday, 25th February, 1960

Ordinary General Meeting for the election of members 5.55 p.m., followed by an Ordinary Meeting at 6 p.m., when a paper will be given by Mr. A. R. Dykes, B.Sc., A.M.I.Struct.E., A.M.I.C.E., on "Folded Plate Construction : An Investigation of Collapse Conditions."

Thursday, 10th March, 1960

Ordinary Meeting at 6 p.m., when three papers on "New Developments in Structural Analysis and Design by means of the Electronic Computer" will be given as follows :—

Mr. L. Morgan : "Application of an Electronic Digital Computer to Structural Steel Design"

Dr. E. Lightfoot, M.I.Struct.E., A.M.I.C.E., and Mr. F. Sawko : "The Analysis of Grid Frameworks and Floor Systems by the Electronic Computer"

Dr. D. M. Brotton, A.M.I.Struct.E. : "Elastic Critical Loads of Multi-Bay Pitched Roof Portal Frames with Rigid External Stanchions"

Thursday, 24th March, 1960

Ordinary General Meeting for the election of members 5.55 p.m., followed by an Ordinary Meeting at 6 p.m., when a paper on "Research for the Concrete Industry" will be given by Dr. A. R. Collins, M.B.E., M.I.Struct.E., M.I.C.E. (Member of Council).

Thursday, 28th April, 1960

An Ordinary General Meeting for the election of members will be held on Thursday, 28th April, 1960, at 5 p.m.

Members wishing to bring guests to the Ordinary Meetings announced above are requested to apply to the Secretary for tickets of admission.

Branch Notices

LANCASHIRE AND CHESHIRE BRANCH

The following meetings have been arranged :—

Friday, 5th February, 1960

Annual Dinner Dance.

In the Derby Suite, Midland Hotel, Manchester.

Monday, 15th February, 1960

Mr. J. D. Davies, M.Sc.(Eng.), A.M.I.Struct.E., A.M.I.C.E., on "Some Problems in Cylindrical Tank Analysis."

Wednesday, 2nd March, 1960

Joint Meeting with the Institute of Welding, 7.15 p.m.

Mr. A. V. Hooker, M.I.Struct.E., M.I.C.E., on "Welding in the Structural Industry."

Thursday, 10th March, 1960

Junior Members' Evening for the presentation of three 20-minute papers by the following Branch members :—

Mr. G. Evans, A.M.I.Struct.E. : "The Design and Construction of the Plutonium Criticality Facility Building at Dounreay."

Mr. T. L. Holden (Graduate) : "The Construction of a Laminated Timber Hyperbolic Paraboloid Roof."

Mr. C. Tucker, A.M.I.Struct.E. : "British Railways —London Midland Region Electrification. Reconstruction of overbridges between Crewe and Manchester."

In the New Lecture Theatre, U.K.A.E.A. (I.G.) Headquarters, Risley, nr. Warrington.

Friday, 18th March, 1960

Dr. D. D. Matthews, M.I.Struct.E., M.I.C.E. (Vice-President), will present a paper from notes provided by M. Esquillan on "The Design and Construction of the Exhibition Palace of the National Centre of Industries and Technology, Paris." It is hoped M. Esquillan will be present.

Thursday, 7th April, 1960

Annual General Meeting.

Unless otherwise stated the above meetings will be held at the College of Science and Technology, Manchester, commencing at 6.30 p.m. Light refreshments will be available from 5.45 p.m.

MERSEYSIDE PANEL

The following meetings have been arranged :—

Monday, 22nd February, 1960

Mr. E. Thorpe, A.M.I.Struct.E., on "The Design and Construction of Windscale Cartridge Cooling Ponds."

At Liverpool University, in the new Civil Engineering Building, Brownlow Hill.

Wednesday, 6th April, 1960

Joint Meeting with the Liverpool Architectural Society.

Mr. Howard V. Lobb, C.B.E., F.R.I.B.A, on "Nuclear Power Stations."

At Bluecoat Chambers, School Lane, Liverpool, commencing at 6 p.m.

Monday, 18th April, 1960

Annual General Meeting of the Merseyside Panel.

At the Liverpool Engineering Society, The Temple, Dale Street, Liverpool.

Unless otherwise stated meetings will commence at 6.30 p.m. and will be preceded by light refreshments from 5.30 p.m.

Hon. Secretary : W. S. Watts, A.M.I.Struct.E., A.M.I.C.E., 11, Newchurch Lane, Culcheth, nr. Warrington, Lancs.

MIDLAND COUNTIES BRANCH

The following meetings have been arranged :—

Friday, 12th February, 1960

Joint Meeting with the Birmingham and Five Counties Architectural Association.

Mr. A. G. Sheppard-Fidler, M.A., B.Arch., L.R.I.B.A. on "Birmingham Rebuilds."

At the Birmingham Medical Institute, 36, Harborne Road, Edgbaston, Birmingham, at 6.15 p.m. Tea will be served from 5.30 p.m.

Friday, 26th February, 1960

Dr. K. C. Rockey, A.M.I.C.E., A.M.I.Mech.E., on "Web Buckling and the Design of Plate Girders."

Tuesday, 8th March, 1960

Mr. A. W. Hill, B.Sc.(Eng.), M.I.Struct.E., M.I.C.E., M.I.Mun.E., on "The Structural Use of Prestressed Concrete in Buildings C.P.115."

At the Electricity Showrooms, Irongate, Derby, at 6.15 p.m. Tea will be served from 5.30 p.m.

Friday, 25th March, 1960

Mr. A. W. Hill, B.Sc.(Eng.), M.I.Struct.E., M.I.C.E., M.I.Mun.E., on "The Structural Use of Prestressed Concrete in Buildings C.P.115."

Friday, 22nd April, 1960

Annual General Meeting, followed by a lecture details of which will be announced.

Unless otherwise stated, meetings will be held at the James Watt Memorial Institute, Great Charles Street, Birmingham, at 6.30 p.m. Tea will be served from 5.45 p.m.

Hon. Secretary: S. M. Cooper, A.M.I.Struct.E., "Applegarth," Hyperion Road, Stourton, nr. Stourbridge, Worcestershire.

GRADUATES' AND STUDENTS' SECTION

The following meetings have been arranged:

Friday, 5th February, 1960

Mr. B. W. Cooper, B.Sc., A.M.I.Struct.E., A.M.I.C.E., Birmingham Office Manager, Truscon Limited, will present a sound film and give an associated lecture on "Picture Frame Construction and Modern Wall Cladding."

Friday, 4th March, 1960

Mr. N. Rayman, Chief Structural Engineer to the City of Coventry, on "The New Coventry."

Friday, 1st April, 1960

Mr. A. T. Clarke, M.I.Struct.E., Branch Chairman, on "Some Experiences and Faults in Reinforced and Prestressed Concrete."

Followed by the 13th Annual General Meeting.

The above meetings will be held at the Birmingham Exchange and Engineering Centre, Stephenson Place, Birmingham, commencing 6.30 p.m. Tea will be served from 6 p.m.

Hon. Secretary: H. T. Dodd, Shepherd's Cottage, Grove Lane, Wishaw, Sutton Coldfield, Warwickshire.

NORTHERN COUNTIES BRANCH

The following meetings have been arranged:

Tuesday, 2nd February, 1960

At Middlesbrough. Mr. N. T. Barrett, B.Sc.(Eng.), A.M.I.Struct.E., (Associate-Member of Council), on "Housing the Dounreay Fast Reactor."

Wednesday, 3rd February, 1960

The above paper will be repeated at Newcastle.

**Tuesday, 16th February*, 1960

At Middlesbrough. Mr. J. H. H. Gillespie, B.Sc., A.M.I.Struct.E., A.M.I.C.E., on "The Modernisation of British Waterways with particular reference to the South Eastern Division."

Friday, 26th February, 1960

Annual Dinner Dance.

At Tilley's Restaurant, Newcastle.

Tuesday, 1st March, 1960

At Middlesbrough. Mr. Walter C. Andrews, O.B.E., M.I.Struct.E., M.I.C.E. (Past President) on "The Provisions of the Revised British Standard for the Use of Structural Steel in Building—B.S. 449/1959."

Wednesday, 2nd March, 1960

The above paper will be repeated at Newcastle.

**Friday, 18th March*, 1960

At Newcastle. Mr. J. H. H. Gillespie, B.Sc., A.M.I.Struct.E., A.M.I.C.E., on "The Modernisation of British Waterways with particular reference to the South Eastern Division."

Tuesday, 5th April, 1960

At Middlesbrough. Mr. Frederick S. Snow, C.B.E., M.I.Struct.E., M.I.C.E., M.I.Mech.E. (Past President), and Mr. E. V. Finn, A.M.I.Struct.E., A.M.I.C.E., on "The Structural Engineering Aspects of the Development of Gatwick Airport."

Wednesday, 6th April, 1960

At Newcastle. Annual General Meeting, after which the above paper will be repeated.

Friday, 22nd April, 1960

Annual Dinner.

At the Corporation Hotel, Middlesbrough.

Unless otherwise stated, meetings in Middlesbrough will be held in the Cleveland Scientific and Technical Institution and meetings in Newcastle will be held in the Neville Hall, commencing at 6.30 p.m., preceded by buffet tea at 6 p.m.

Hon. Secretary: P. D. Newton, B.Sc., A.M.I.Struct.E., A.M.I.C.E., c/o Richard Hill Ltd., P.O. Box 29, Middlesbrough, Yorkshire.

NORTHERN IRELAND BRANCH

The following meetings have been arranged:

Tuesday, 2nd February, 1960

Mr. R. Boorman, F.R.Ae.S., on "Aircraft Structures."

Tuesday, 1st March, 1960

Annual Function.

Tuesday, 5th April, 1960

Annual General Meeting and Film Evening.

Meetings will be held in the Civil Engineering Department of the Queen's University of Belfast at 6.30 p.m., unless otherwise notified, and will be preceded by tea at 5.45 p.m.

Hon. Secretary: L. Clements, A.M.I.Struct.E., A.M.I.C.E., A.M.I.Mun.E., 3, Kingswood Park, Cherryvalley, Belfast.

SCOTTISH BRANCH

The following meetings have been arranged:

Friday, 19th February, 1960

Combined Meeting with the West of Scotland Branch of The Institution of Civil Engineers.

Mr. N. M. Brydon, M.B.E., B.Sc., M.I.Struct.E., M.I.C.E., on "Concrete."

Tuesday, 15th March, 1960

Mr. W. G. N. Geddes, B.Sc., M.I.Struct.E., M.I.C.E., on "Piling in Structural Engineering."

Tuesday, 19th April, 1960

Annual General Meeting.

The above meetings will be held at The Institution of Engineers and Shipbuilders, 39, Elmbank Crescent, Glasgow, commencing 7 p.m.

Hon. Secretary: W. Shearer Smith, M.I.Struct.E., A.M.I.C.E., c/o The Royal College of Science and Technology, George Street, Glasgow, C.1.

Additional meetings to those announced in the printed Sessional Programme.

SOUTH WESTERN SECTION

The following meetings have been arranged :

Friday, 12th February, 1960

In Torquay. Mr. M. R. Hawkins, A.M.I.Struct.E., on " The Structural Engineer in Municipal Engineering."

Venue and time of meeting to be announced.

Friday, 11th March, 1960

In Plymouth. Mr. J. D. Norfolk, M.I.Struct.E., A.M.I.C.E., A.M.I.Mun.E., on " The New Queen Elizabeth Dock at Falmouth."

At the Duke of Cornwall Hotel, 6 p.m. Tea at 5.30 p.m.

Hon. Secretary : C. J. Woodrow, J.P., " Elstow," Hartley Park Villas, Mannamead, Plymouth, Devon.

WALES AND MONMOUTHSHIRE BRANCH

The following meetings have been arranged :

Thursday, 11th February, 1960

At Cardiff. Mr. E. W. H. Gifford, B.Sc., M.I.C.E., A.M.I.Struct.E., and Mr. H. E. Lewis, M.Sc., on " Some Long Span Prestressed Bridges."

Wednesday, 9th March, 1960

At Swansea. Junior Members' Evening. Papers will be given by Graduates and Students.

Friday, 8th April, 1960

Annual Dinner.

At Swansea.

Meetings at Cardiff will be held at the South Wales Institute of Engineers, Park Place, and in Swansea at the Mackworth Hotel, High Street, commencing 6.30 p.m.

Hon. Secretary : K. J. Stewart, M.I.Struct.E., A.M.I.C.E., 15, Glanmor Road, Swansea.

WESTERN COUNTIES BRANCH

The following meetings have been arranged :

Friday, 5th February, 1960

Joint Meeting with the Bristol and Somerset Society of Architects :

Forum—J. T. Redpath, M.B.E., A.R.I.B.A., Architect
C. D. Browning, A.R.I.C.S., Quantity Surveyor
F. V. Allen Contractor
J. B. Bennett, M.I.C.E., M.I.Mun.E., Engineer
Question Master The Chairman

Tuesday, 16th February, 1960

Annual Dinner and Dance. At the Ashton Court Country Club, Bristol, from 7.30 p.m. to 1 a.m.

Friday, 4th March, 1960

Combined Meeting with the Institution of Civil Engineers.

Mr. H. G. Cousins, B.Sc., M.I.Struct.E., M.I.C.E., on " Concrete Structures."

Friday, 1st April, 1960

Annual General Meeting 6 p.m., followed at 7 p.m., by a paper to be given by Mr. John Mason, B.A.(Cantab.), M.I.Struct.E., A.M.I.C.E. (Hon. Treasurer) entitled " A Commentary on the new British Standard 449 (1959). The Use of Structural Steel in Building."

Meetings will be held in the Small Lecture Theatre, University Engineering Laboratories, University Walk, Bristol 8, commencing 6 p.m., preceded by tea at 5.30 p.m.

Hon. Secretary : A. C. Hughes, M.Eng., A.M.I.Struct.E., A.M.I.C.E., 21, Great Brockeridge, Bristol, 9.

YORKSHIRE BRANCH

The following meetings have been arranged :

Wednesday, 17th February, 1960

At Leeds. Mr. E. Longbottom, B.Sc., A.M.I.Struct.E., A.M.I.C.E., on " The Future of Military Bridge Design."

Wednesday, 2nd March, 1960

At Scunthorpe. Joint Meeting with the East Midlands Association of the Institution of Civil Engineers.

Dr. K. C. Rockey, A.M.I.C.E., A.M.I.Mech.E., on " Web Buckling and the Design of Web Plates."

At the Blue Bell Hotel, 6.30 p.m.

Wednesday, 16th March, 1960

At Leeds. Joint Meeting with the Yorkshire Association of The Institution of Civil Engineers and the Yorkshire and Lincolnshire Branch of the Institution of Highway Engineers.

Mr. J. M. Fisher, B.Sc., M.I.C.E., Dr. A. R. Lee, A.I.C.E., and Dr. R. S. Millard, M.I.C.E., on " Research and its Application to Road Construction."

Wednesday, 23rd March, 1960

At Hull. Joint Meeting with the Hull and East Riding Branch of the Institution of Civil Engineers.

Mr. F. R. Bullen, B.Sc.(Eng.), M.I.Struct.E., M.I.C.E., (Vice-President) on " The Bearing Capacity of Driven Piles."

In the Lecture Theatre, Electricity Building, Ferensway, 6.15 p.m.

Friday, 1st April, 1960

At York. Annual Dinner and Dance.

At the Royal Station Hotel, 7 p.m.

Wednesday, 6th April, 1960

At Sheffield. Mr. H. J. Purkis, B.A., B.Sc., on " The Present Position of Sound Insulation in Buildings."

Wednesday, 20th April, 1960

At Leeds. Annual General Meeting, followed by a paper given by Mr. E. J. Martin, M.I.Struct.E., entitled " Reinforced Concrete Construction for a new Limestone Quarrying and Treatment Plant."

Meetings in Leeds will be held at the Metropole Hotel, King Street, and in Sheffield at the Royal Victoria Hotel. Meetings will commence at 6.30 p.m., preceded by buffet tea at 6.15 p.m.

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Book Reviews

Analysis of Pipe Structures, by John Gascoyne. (London : Sir Isaac Pitman, 1959.). 9¾ in. × 7 in. 181 + xiii pp. 45/-

This book presents an introduction to the subject of pipe flexibility sufficiently comprehensive to enable the designer to conduct a careful routine analysis of simple pipe structures under normal office conditions without recourse to any special equipment. A knowledge of mechanics, the design of structures and the strength of materials has been assumed, but complicated multi-anchor systems requiring an intimate knowledge of the calculus are not included.

In the introductory chapter stress conditions applying particularly to piping problems are considered briefly, after which the limitations imposed by British and American codes and Standards are studied. Methods of stress calculation are then considered, with particular reference to the elastic-centre method, and chapters follow on the translation of the results of the calculations of thrust and stress. Expansion joints are dealt with in some detail, and a chapter is devoted to pipe supports.

The volume concludes with complete analyses for a simple single-plane two-anchor structure and a simple two-anchor, three-plane pipe structure. Appendixes contain useful tables and other data. For convenience in handling, the book has a wire spiral binding, so that when opened it will lie flat.

Fundamentals of Boiler House Technique, by P. D. Dehnel. (London : Hutchinson : 1959) 9¼ in. × 5¾ in. 164 + ix pp. 25/-.

This book deals with the many aspects of boiler technology, consideration being given to the descriptive side of the subject and also to the theory. The various chapters under the headings modern boilers, water treatment, formation and properties of steam, fuels, combustion, combustion calculations, fuel and flue gas testing, draught, atmospheric pollution and boiler efficiency and testing are more or less self-contained, so that they can be studied independently. A number of worked examples are given where applicable, and graded problems are included at the end of each chapter.

The book will be useful to students requiring a knowledge of fuel and combustion engineering, and to boiler house personnel.

Dictionary of Civil Engineering and Construction Machinery and Equipment, 2nd. Edition. Vol. 1. German-English. (Wiesbaden : Bauverlag G. m. b. H. 1958 : London : Contractors Record.). 6½ in. × 4½ in. 499 pp. 65/-.

This is the first volume of the second edition of a useful technical dictionary first published in 1956 in one volume. By dividing the publication into two volumes it has been possible to add a considerable number of new terms and related words and expressions while keeping to a convenient workable size.

The terms are compiled in alphabetical order, but in a number of cases lists of words or expressions relevant to a particular subject are listed as a sub-section under the main heading, thus adding to the value of the publication.

Bibliography of Effects of Soil Conditions on Earthquake Damage, by C. Martin Duke. (San Francisco, California : Earthquake Engineering Research Institute, 1958.) 10½ in. × 7 in. 47 + iii pp. $1.00.

This is a detailed bibliography containing more than two hundred and seventy-five annotated entries arranged under general references, destructive earthquakes, ground motion and soil-structure system. It will be a useful guide to all who are interested in earthquake engineering.

The British Engineers' Association Handbook, 1959. (London : The Association) 8½ in. × 5½ in, 636 pp. 21/-.

This volume is divided into four sections, the first containing an alphabetical list of members with names and addresses, telephone numbers, etc., together with range of products, and an index of the members announcements which make up Section II. Section III contains a classified list of manufactures, and a useful section on trade names and marks completes the volume. A guide to the contents is given in English, French, German, Portuguese and Spanish, and the lists of manufactures are also given in the five languages.

A Dictionary of Civil Engineering, by J. S. Scott. (Harmondsworth, Middlesex: Penguin Books, 1958). 7 in. × 4¼ in., 415 pp. 5s.

This small volume contains definitions for about five thousand technical terms related to civil engineering and will be a useful book of reference for engineers and technical libraries.

Practical Problems in Soil Mechanics, 3rd. Edition, by H. R. Reynolds and P. Protopapadakis. (London : Crosby Lockwood, 1959). 8½ in. × 5½ in. 223 + xii pp. 21/-.

This book, first published in 1957, presents in a simple manner the application of soil mechanics methods and analyses to practical problems, reducing the use of mathematics to a minimum and avoiding the analytical approach to the solution of problems.

In the third edition additional material has been included to cover more recent developments in soil mechanics, such as the provision of sand drains and sand piles for constructing roadways over soils of very weak bearing capacity, the effects of vibration on soils, the use of piled foundations, and the determination of soil moisture and soil density by nuclear radiation.

Numerous worked problems are given throughout the book to illustrate the more important aspects of the subject, and a bibliography has been included at the end of the volume.

" Editorial Notes from Concrete and Constructional Engineering," by H. L. Childe. (London: Concrete Publications). 9 in. × 6 in., 96 pp. 7s. 6d.

The thirty-eight essays reprinted in this book, relate specifically to structural and civil engineering, but apply to technologists in all industries. The author's comments on the sayings and writings of technologists, indicate the pitfalls that beset those who have not developed an inquiring and logical mind, and whose loose thinking results in statements that those who made them no doubt thought were profound truths but which are shown to be half-truths or nonsense. Examples, and the constructive advice throughout the book, are intended to encourage and help the young technologists to write and say exactly what they mean, and particularly to pursue a course of study that will fit them for the higher posts that await technical men.

Building Regulations Handbook, 5th Edition. (London : The Royal Society for the Prevention of Accidents, 1959). 11 in. × 8¼ in., 28 pp. 10s.

Just over ten years ago the Building (Safety, Health and Welfare) Regulations, 1948, came into force. Recognizing the importance of this comprehensive code of legislation as a factor in the reduction of accidents in a hazardous industry, the Royal Society for the Prevention of Accidents immediately published its Building Regulations Handbook. The intention of this publication was to assist the implementation of the Regulations by grouping them into sections which simplified understanding of the nature and extent of their provisions. Subsequent amendments to the principal Regulations, particularly those introduced by the Amendment Regulations of 1952 and 1958, necessitated revised editions, culminating in this 5th Edition.

The Duodecimal Book with Tables, 2nd Edition, by L. A. Poulden. (London : Cleaver-Hume Press Ltd., 1959). 7¼ in. × 4¾ in., 320 pp. (including tables) 15s.

The enlarged second edition of this book includes, apart from a number of minor amendments, an extended introduction to the methods of calculating in duodecimals, explaining the operations of addition, subtraction, division and multiplication.

The tables are arranged for quick reference, each section relating to one dimension, from 0.1 to 11.11, and giving 144 multiples of it within the same range, with "difference" figures and longer multiples at the foot.

The book is intended mainly for use in architects' surveyors', builders' and kindred offices, and will be found of considerable value wherever the duodecimal system is used.

Proceedings of the Third Congress of the Fédération Internationale de la Précontrainte, Berlin, 1958. (London : Cement and Concrete Association, 1958). 9½ in. × 6 in., 766 plus viii pp. 2 Volumes £13. (£10 to members of Groups & Associations affiliated to F.I.P.)

The Proceedings of the Third Congress of the Fédération Internationale de la Précontrainte are being published in two volumes, the first, containing all the papers and general reports presented, and the second containing the discussions and also a brief chronicle of the Congress, the complete list of members, lists of officers and committees and an index of authors and contributors.

Papers and discussions at the Congress were grouped under three headings, development in design methods, progress in prestressing techniques as applied on site, and progress in the manufacture of factory-made precast units. In the first session, twenty-four papers were presented dealing with compressive strength, flexural strength, shear strength, torsional strength, stresses in shells, prestressing of pressure tunnels and bridges. Some papers dealt with special structural forms and the considerations of prestress in building codes. In the second session there were seventeen papers dealing with problems encountered in prestressed concrete constructional practice, such as grouting, friction, anchorages, properties of steels and glass fibre, and also a paper on mass precasting of prestressed concrete trusses and beams, and one on the construction of the Nahe viaduct near Bingen. Nineteen papers were presented in the third session on factory processes, development of bond, bridge beams, piles, assembly by prestressing on site of precast units, composite construction and general items of interest.

Each paper and contribution is printed in the language—English, French, German or Spanish—in which it was written or delivered. The general reports and summaries of the papers are given in all the four languages of the Congress.

The Congress, which was held in Berlin in 1958, was attended by representatives from forty-two countries, whilst authors from twenty countries presented papers. The Proceedings which show that remarkable progress has been made in some fields in recent years, will be of considerable value to structural engineers interested in prestressed concrete design and construction.

Welding Handbook, 4th Edition, Section II. Welding Processes : Gas, Arc and Resistance, Edited by A. L. Phillips. (New York : American Welding Society, 1958 ; London : Cleaver-Hume Press). 9 in. × 6 in., 528 pp. illustrated, 72s.

This is the second of the five parts of the revised edition of the American Welding Society Handbook, the first part of which was reviewed in " The Structural Engineer " in February 1959. This volume, dealing with gas, arc and resistance welding processes, incorporates technological advances made since the third edition was published, and, as in the case of the first part, the material included is based on data obtained from all sections of the American Welding Industry. Each chapter concludes with a bibliography of material suggested for further study and the comprehensive index contains many cross references.

The book is attractively produced and contains 375 line and 60 half-tone illustrations and 97 tables.

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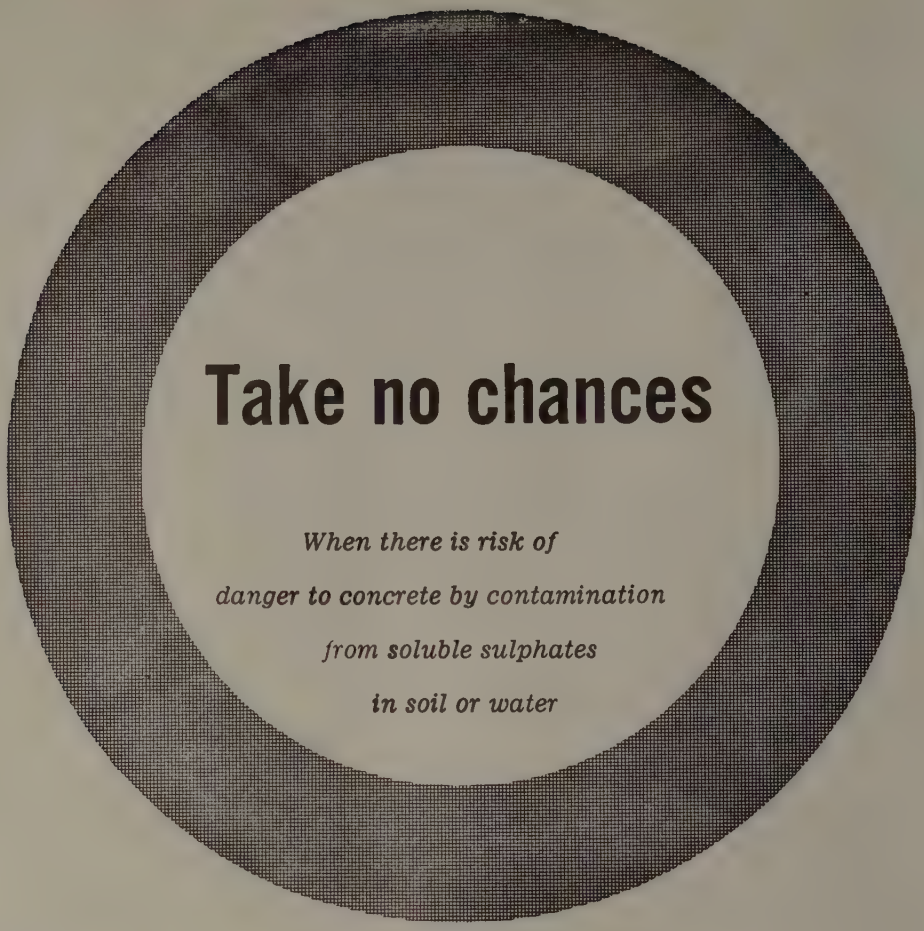

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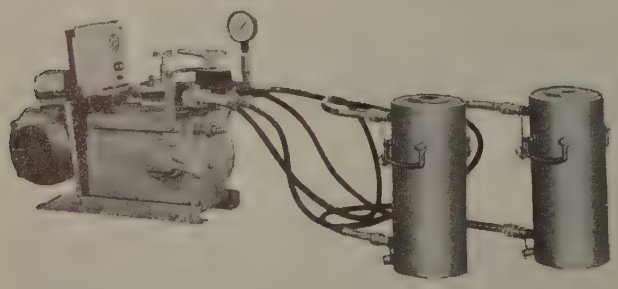

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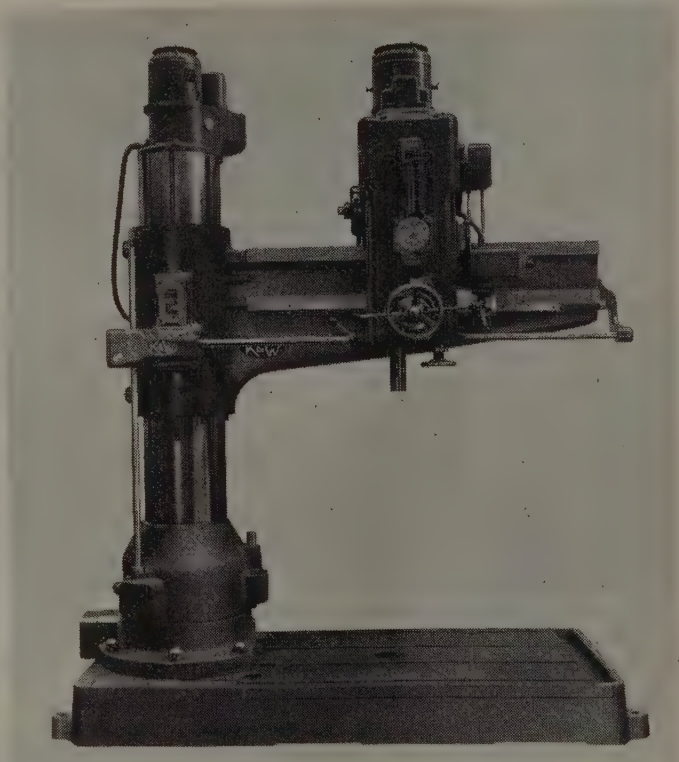

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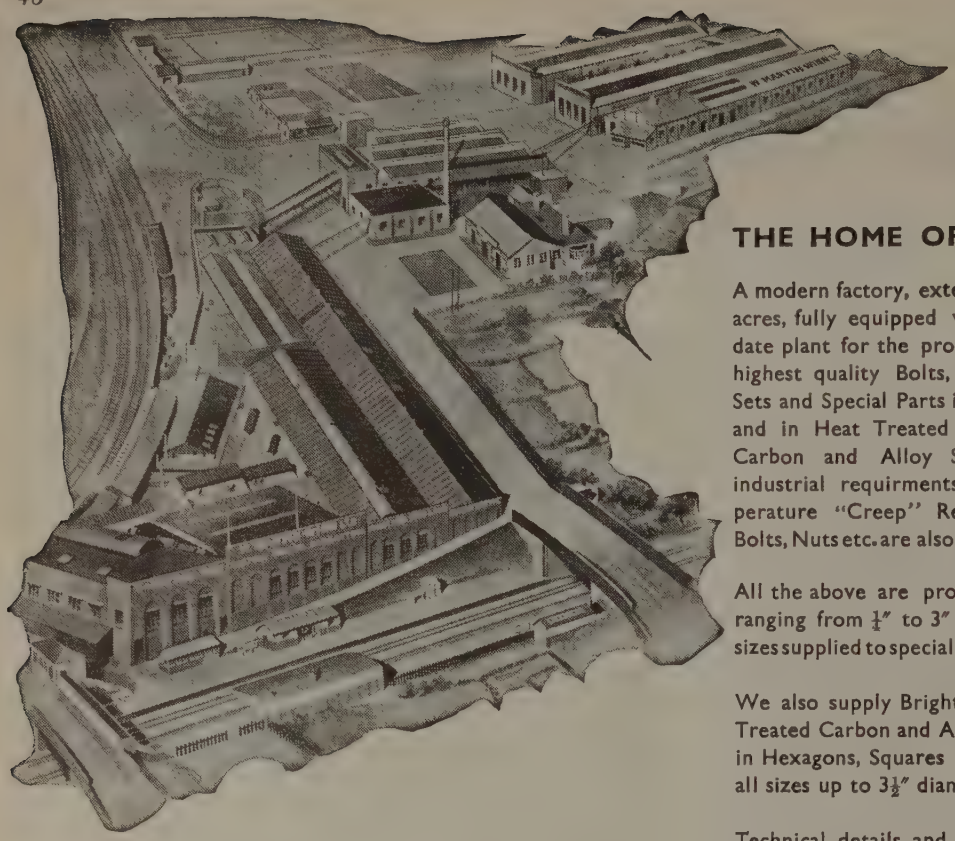

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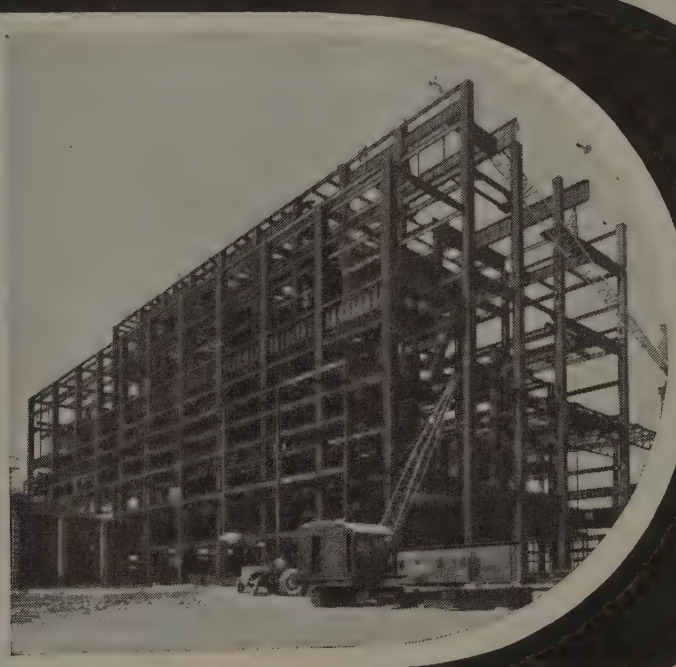

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ASSISTANT Engineer (Civil) required for their London Office by the Crown Agents for Oversea Governments and Administrations for appointment to pensionable establishment on probation for two years. Commencing salary between £830 at age 25, and £1,125 at age 34 or over, in scale rising to £1,300. Prospects of promotion. Fully qualified officers at least 27 years of age may be eligible for special increase of £75 after two years service. Liberal leave. Five day week. Candidates must be Corporate members of the Institution of Civil Engineers or the Institution of Structural Engineers or, if below the age of 28, must have passed Parts I and II of the Associate Membership examination of the Institution of Civil Engineers or hold an exempting degree, or have passed the Associate Membership examination of the Institution of Structural Engineers. They must be good draughtsmen and have had experience in the design of bridges, buildings or other structures in steel or reinforced concrete. Site experience an advantage. Candidates must be prepared to spend periods on site surveys overseas in which event special overseas allowances are payable. Write to the Crown Agents, 4, Millbank, London, S.W.1. State age, name in block letters, full qualifications and experience and quote M2A/42637/SAD.

BRADFORD INSTITUTE OF TECHNOLOGY. Principal: E. G. Edwards, Ph.D., B.Sc., F.R.I.C.—Applications are invited for the post of Principal Lecturer in Civil Engineering. Candidates should possess the qualifications and experience to direct research and post graduate work and to take a leading part in advanced teaching. Corporate membership of at least one of the professional Institutions associated with Civil Engineering and extensive professional experience are essential. The successful candidate will be expected to assist the Head of Department with the administrative work of the Department. Salary Scale £1,750 to £1,900 per annum. Previous industrial and research experience at a suitable level will be taken into account in fixing the commencing salary. Further particulars and forms of application may be obtained from the Registrar, Bradford Institute of Technology, Bradford, 7. W. H. Leathem, Clerk to the Governors.

CIVIL Engineering Appointment, McMaster University—The Department of Civil Engineering and Engineering Mechanics solicits applications for a staff position in a new school with a stimulating research environment. The candidate should possess a graduate degree (preferably the doctorate) based on specialization in structures, and some experience in lecturing and research direction. Duties will include undergraduate and graduate instruction, and good research facilities are available. Appointment will be made at the rank of assistant or associate professor, depending upon qualifications and experience. Enquiries and the names of three references should be addressed to: N. E. Wilson, A.M.I.Struct.E., Civil Engineering, McMaster University, Hamilton, Ontario, Canada.

BRITISH RAILWAYS—Western Region.—Applications are invited for Structural Draughtsman experienced in preparing estimates and contracts for the supply and erection of steel and concrete bridges, etc. Drawing Office and costing experience essential. Salary range £833 to £903. Travel concessions, holidays with pay with prospects of promotion and permanency with membership of Superannuation Fund. Applications stating age, previous experience, etc., to Chief Civil Engineer, B.R., Western Region, Paddington Station, London, W.2.

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SURREY EDUCATION COMMITTEE

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CIVIL Engineering Contractors specialised in Reinforced Concrete seek a designer-draughtsman experienced in structural steel and/or heavy machinery for special jobs in connection with plant and temporary works. Write or telephone to Chief Engineer, Peter Lind & Co. Ltd., Romney House, Tufton Street, London, S.W.1. Tel. : Abbey 7361.

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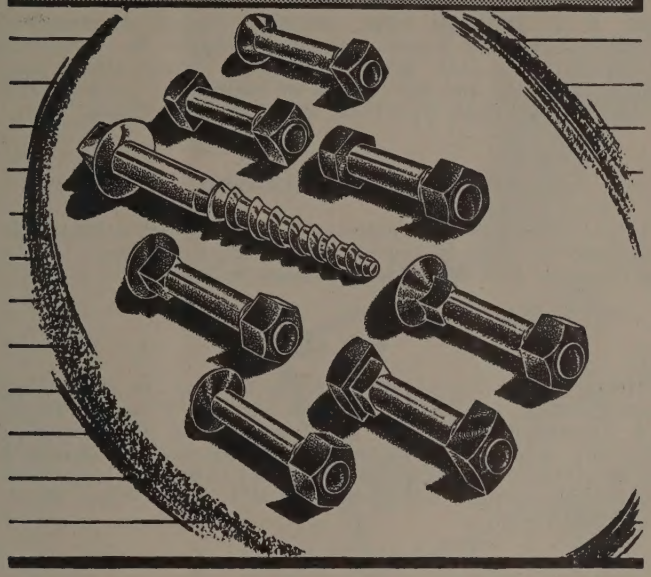

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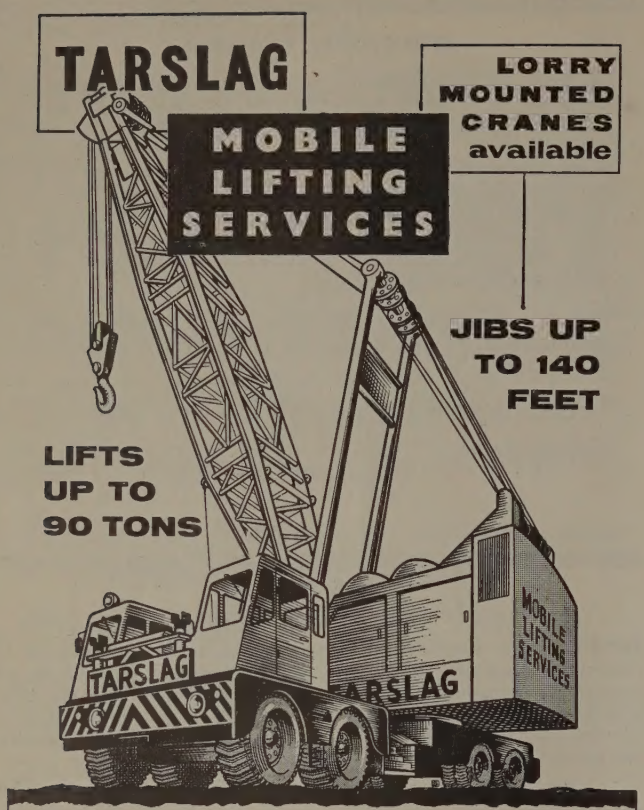

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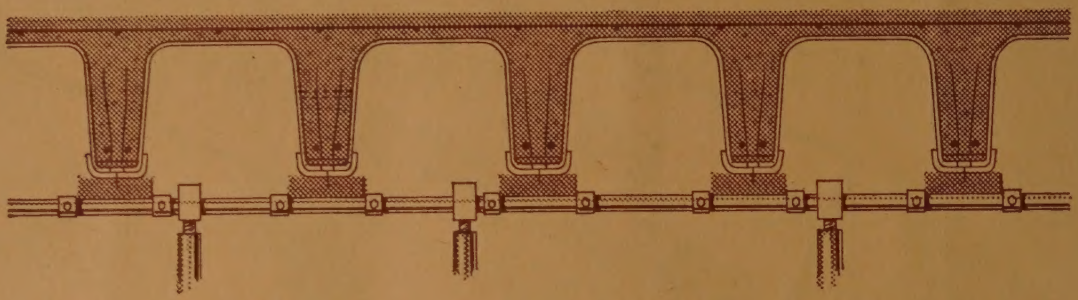

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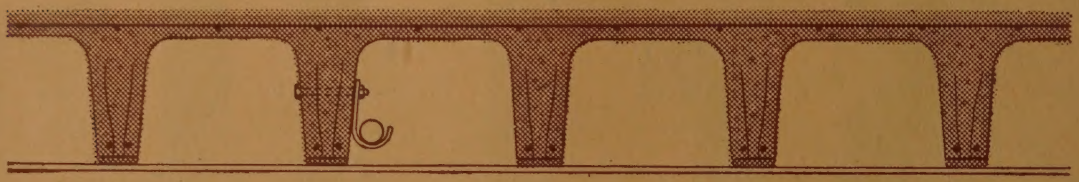

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